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Vegetation Monitoring: an Annotated Bibliography

Compilers:
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The Compilers

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Angela G. Evenden is a Botanist and Natural Areas Program Manager with the Intermountain Research Station in Missoula, MT. She holds a B.A. degree in botany and German, an M.S. degree in range ecology, and a Ph.D. degree in botany from Oregon State University.

Research Summary

This annotated bibliography documents literature addressing the design and implementation of vegetation monitoring. This bibliography provides resource managers, ecologists, and scientists access to the great volume of literature addressing many aspects of vegetation monitoring: planning and objective setting, choosing vegetation attributes to measure, sampling design, sampling methods, statistical and graphical analysis, and communication of results. Over half of the 1,400 references have been annotated. Keywords pertaining to the type of monitoring or method are included with each bibliographic entry. Entries are indexed by keywords.

Acknowledgments

This bibliography was completed under a cooperative agreement between the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, and Alderspring Consulting, Tendoy, ID. We gratefully acknowledge the Forest Service's Washington Office for financial support in printing this bibliography.

Contents

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Introduction

Ecological research in recent years has yielded significant new insights into the complexities of ecosystems that land management agencies, including the USDA Forest Service, are charged with managing. This new knowledge, coupled with growing concern for maintaining sustainable ecosystems, has resulted in the need to develop more efficient and effective approaches to natural resource monitoring. Monitoring of vegetation comprises a significant component of natural resource monitoring efforts. Vegetation provides habitat for many other species, provides ecosystem functions, and serves as an integrator of environmental effects.

As a basis for designing monitoring projects, and developing new approaches, it is important to build on existing knowledge. This annotated bibliography documents literature addressing the design and implementation of vegetation monitoring. This bibliography provides resource managers, ecologists, and scientists access to the great volume of literature addressing many aspects of vegetation monitoring: planning and objective setting, choosing vegetation attributes to measure, sampling design, sampling methods, statistical and graphical analysis, and communication of results. The information in this bibliography provides a foundation for developing vegetation monitoring projects.

References have been drawn from the plant and community ecology, conservation biology, resource management, remote sensing, landscape ecology, and statistical literature. Clearly the number of references available within each of these disciplines is voluminous. We have attempted to select those references most directly applicable to monitoring vegetation as well as references describing techniques that may be underutilized. For example, selections from the statistical literature include standard statistical texts, as well as papers and books addressing rarely used but potentially valuable techniques for analyzing monitoring data such as repeated measures analysis, time series, and Bayesian statistics. From the vast information available on multivariate techniques such as ordination and classification, we selected references that describe techniques specifically applicable to situations involving community change. We also limited the references primarily to terrestrial ecosystems. The references on aquatic systems were selected because of their applicability to issues and methodological problems that also occur in monitoring of terrestrial vegetation.

Our search methods included a combination of computerized literature and library searches. An initial search of computerized bibliographic data bases entailed a variety of keyword combinations. The data bases we searched included AGRICOLA (USDA), BIOSIS Previews, and FS INFO. After this, manual library searches were conducted. Recently published papers on vegetation monitoring and key symposia proceedings and references were used to identify important papers and publications. From this effort, specific journals were identified for more indepth searching (see "Journals List" section). In addition, we contacted key researchers and organizations involved with vegetation monitoring.

Over half of the 1,400 references have been annotated. The annotations differ from abstracts in that they extract and summarize the vegetation monitoring information from each reference. Some of these references are fairly old, some dating back to the 1930's. Many of the issues of importance in vegetation monitoring, such as choosing among measurable attributes such as cover, density, and frequency, were explicitly addressed in these early papers. A large number of studies comparing different field techniques were published in the middle of this century as early plant ecologists struggled with developing effective methods for measuring vegetation.

How to Use This Bibliography

Keywords have been assigned to all references (see "Keywords List" section), and a complete list of references associated with each keyword is provided in the "Keyword Index." The words and phrases selected evolved over the life of the project, and the list was reassessed and reassigned several times. The keywords provide both general and specific searching capabilities.

Keywords are arranged by subject groups. For each subject group, a single keyword or phrase has been assigned that functions as a general search term (shown in italics in the "Keywords List" section). This general search term will access all references that have been assigned one of the specific keywords within that subject heading. For example, under the general subject of REMOTE SENSING AND GIS, the general search term is *remote sensing*. If you are interested in remote sensing and vegetation monitoring in general, a search using this keyword will access all literature related to remote sensing. If you are interested in only aerial photography, however,

your search would be much more effective if you used that specific keyword. Effective searching may also involve a combination of keywords.

Keyword searches will often include papers that appear only peripherally relevant. This was deliberate on the part of the authors to ensure that all papers related to a subject would result from a search.

The bibliography is arranged alphabetically by author with a number assigned to each entry. It is that number that relates to the numbers in the "Keyword Index." Each entry in the bibliography contains a citation, followed by an annotation (where completed), and then a list of keywords. Keywords are separated by a comma. References cited within annotations can be found in the bibliography.

Management of the bibliographic data for this project was facilitated by use of Procite bibliographic software. All citations and annotations were entered into a PROCITE data base. This data base is available in either Procite 2.0 or ASCII format from the second author, who can be reached at:

Forestry Sciences Laboratory
USDA Forest Service
P.O. Box 8089
Missoula, MT 59807

Journals List

This is a comprehensive list of journals included in the bibliography. An asterix (*) indicates that a particular journal was searched in depth in compiling the bibliography.

Abstracta Botanica
Acta Botanica Neerlandica
Acta Stereologica
Agronomy Journal
Ambio
American Journal of Botany
American Journal of Epidemiology
American Midland Naturalist*
American Naturalist*
American Scientist
American Statistical Association Journal
American Statistician
Annales Bontanici Fennici
Annals of Botany
Annals of Mathematics and Statistics
Annual Review of Ecology and Systematics*
Aquatic Botany*
Aquatic Conservation
Arctic and Alpine Research
Audubon Field Notes
Australian Journal of Botany*
Australian Journal of Ecology*
Australian Journal of Experimental and Agricultural Animal Husbandry
Australian Journal of Marine and Freshwater Research
Australian Journal of Scientific Research
Australian Rangeland Journal
Biodiversity and Conservation
Biological Conservation*
Biological Journal of the Linnean Society of London
Biologist
Biometrical Journal
Biometrics
Biometrika
Bioscience
Biotropica
Botanical Review
Botany Review
Bulletin of Marine Science
Bulletin of the Ecological Society of America*
Bulletin of the Torrey Botanical Club
California Fish and Game
Canadian Journal of Botany*
Canadian Journal of Fisheries and Aquatic Sciences
Canadian Journal of Forest Research*
Canadian Journal of Forestry*
Canadian Journal of Plant Science*
Castanea
Conservation Biology*
Ecological Applications*
Ecological Bulletin
Ecological Modelling*
Ecological Monographs*
Ecology*
Encyclopedia of Statistical Sciences
Environment
Environment International
Environmental Conservation
Environmental Entomology
Environmental Impact Assessment Review
Environmental Management
Environmental Management and Assessment
Environmental Monitoring and Assessment
Environmental Research
Environmental Science and Technology
Estuaries
Estuarine, Coastal and Shelf Science
Folia Foristalia
Forest Science*
Forest Science Monograph 31, Supplement
Forestry

Forestry Chronicle
Forestry Commission Bulletin 108
Forestry Science
Geoderma
Geology
Grass and Forage Science
Great Basin Naturalist*
Hortscience
Hydrobiologia
International Journal of Remote Sensing
International Statistical Review
Israel Journal of Botany
Journal of Agricultural Research
Journal of Agricultural Science
Journal of the American Statistical Association
Journal of Applied Ecology*
Journal of Arid Environments
Journal of Biogeography
Journal of Botany*
Journal of Coastal Research
Journal of Ecology*
Journal of Economic Entomology
Journal of Environmental and Economic Management
Journal of Environmental Management
Journal of Environmental Sciences
Journal of Experimental Marine Biology and Ecology
Journal of Forestry*
Journal of Range Management*
Journal of Soil Conservation
Journal of Testing and Evaluation
Journal of the Air Waste Management Association
Journal of the American Society of Agronomy
Journal of the American Statistical Association
Journal of the British Grassland Society
Journal of the Grassland Society of Southern Africa
Journal of the Marine Biological Association of
the United Kingdom
Journal of the Royal Statistical Society Series A
Journal of Theoretical Biology
Journal of Vegetation Science*
Journal of Wildlife Management
Land Degradation and Rehabilitation
Landscape and Urban Planning
Landscape Ecology*
Marine Ecology Progress Series
National Geographic Research
Natural Areas Journal*
Nature
Nature Conservancy News
New Phytologist
New Zealand Agricultural Journal
New Zealand Ecological Society Proceedings
New Zealand Journal of Botany*
New Zealand Journal of Ecology*
New Zealand Journal of Forestry
Nordic Journal of Botany
Northwest Science*
Oecologia*
Oikos*
Paleobiology
Park Science
Permanent Plotter: A Newsletter of the Ecological
Society of America
Philosophical Transactions of the Royal Society of
London B
Photogrammetric Engineering and Remote Sensing
Physiology and Ecology
Phytocoenosis
Proceedings of the Grassland Society of Southern
Africa
Proceedings of the Indiana Academy of Science
Proceedings of the New Zealand Ecological Society
Psychology Bulletin
Rangeland Journal
Rangelands
Reef Research
Remote Sensing of the Environment
Restoration and Management Notes
Restoration Ecology
Revista SELPER
Science
Search
South African Journal of Wildlife Research
The Southwestern Naturalist
Statistical Journal of the United Nations ECE
Technometrics
Trends
Trends in Ecology and Evolution*
Unasylva
U.S. Geological Survey Journal of Research
Vegetatio*
Water Research
Water Resources Bulletin
Water Resources Research
Western Journal of Applied Forestry
Wildlife Society Bulletin

Keywords List

Keywords are arranged by general subject (all capitalized). Within each general subject, one or two keywords appear in italics at the head of the list; these are general search terms. Using a general search term will access all literature that has been assigned one of the more specific keywords listed in regular typeface. Effective searching may involve the use of a combination of keywords.

GUIDANCE, EXAMPLES, OVERVIEWS

monitoring overviews

agency guidance and policy
agency plans
general book on monitoring
monitoring definitions
vegetation sampling overview

RELATED SUBJECTS

inventory

TYPES OF MONITORING

general examples
monitoring examples

baseline monitoring
ecological monitoring programs
environmental monitoring programs
global change monitoring
integrated monitoring
large-scale monitoring
long-term ecological monitoring

SPECIAL SITES

special sites

national parks
natural areas
protected areas
reference areas
wilderness

OBJECTIVE SETTING

monitoring and management objectives

adaptive management
biological significance
ecological models
feedback loops
interdisciplinary design
natural variability
predicting change
resource management

LANDSCAPE

landscape-level

biodiversity
corridors
disturbance
ecological processes
ecosystem
ecosystem management
fragmentation
functional groups
habitat management
indicators
landscape change
landscape patterns
landscape planning
patch dynamics
pattern
prescribed fire
regional planning
restoration
scale
vegetation treatments

COMMUNITY

community-level

community change
community classification
community comparisons
community composition
community structure
cover typing
diversity indices
ecotones
habitat mapping
plant associations
species diversity
species lists
species richness
succession
vegetation mapping

ECOSYSTEM TYPES

alpine
aquatic
arctic
coniferous forest
deciduous forest
desert
forest
grassland
meadow
rangeland

riparian
savanna
shrub grassland
shrubland
wetland
woodland

FIELD TECHNIQUES

***field technique*s**
technique comparison

FIELD TECHNIQUES: DENSITY

density

angle-order
distance methods
nearest neighbor
plotless methods
point-center methods
random pairs
variable plots
wandering quarter

FIELD TECHNIQUES: COVER

cover

basal area
canopy cover
charting
cover classes
line intercept
loop frames
ocular estimation
point frames
point intercept
variable plots

FIELD TECHNIQUES: PRODUCTION

production

biomass
canopy volume
double sampling
dry-weight-rank
weight estimate

FIELD TECHNIQUES: OTHER

crown diameter
DBH
frequency
heights
monumentation
nested frequency
observer variability
performance
photoplots
photopoints
releve
soils
specimen curation
tools
tree-ring analysis
utilization
video

REMOTE SENSING AND GIS

remote sensing

aerial photography
AVHRR
GIS
GPS
Landsat
MSS
TM
SPOT

STUDY DESIGN

sampling design

BACI
cluster sampling
data management
detecting change
experimental design
permanent plots
pilot study
plot dimensions
plot selection
power
precision
pseudoreplication
random sampling
replication
sample size
stratified sampling
systematic sampling
two-stage sampling
Type I and Type II errors

ANALYSIS

analysis

ANOVA
Bayesian statistics
bootstrap
categorical data analysis
classification
clustering

confidence intervals
covariance
gradient analysis
graphical analysis
jackknife
MANOVA
multiple comparisons
multivariate analysis
nonparametric statistics
ordination
parametric statistics
randomization tests
repeated measures analysis
similarity measures
statistical interpretation
statistics overview
time series
trend analysis

INDIVIDUAL SPECIES

annuals
demographic techniques
exotics
herbaceous species
rare species
seedbank
seedling
shrub
tree

Bibliography

1. Aberdeen, J. E. C. 1958. **The effect of quadrat size, plant size and plant distribution on frequency estimates in plant ecology**. Australian Journal of Botany. 7: 47-58.

The author describes how frequency measures are affected by quadrat size, the size of plants, the spatial distribution of plants (random or contagious), and density. Frequency is described as a synthetic measure that combines all of these attributes; thus, a frequency measure cannot readily be visualized or understood in terms of familiar plant characteristics. For example, two communities may contain the same frequency of a species, but may not exhibit the same density or distribution. Density can be calculated from frequency if the average diameter of the plants is known and if their spatial distribution is random; most plant populations, however, are spatially aggregated. Density can also be calculated in non-random populations if the following is known: the average size of plants, the average radius of the aggregated clumps, the average density of occurrence of the clumps and the proportion of the aggregated clump area that is actually occupied by plants. Degree of contagion can also be calculated from frequency values for two plot sizes combined with data on the size of the average plant. Frequency values from several plot sizes can be used to detect departures from random distributions.

design, plot dimensions, field techniques, technique comparison, density, frequency.

2. Aberdeen, J. E. C. 1957. **The uses and limitations of frequency estimates in plant ecology**. Australian Journal of Botany. 5: 86-102.

field techniques, frequency.

3. Achen, C. H. 1986. **Statistical analysis of quasi-experiments**. Berkeley, CA: University of California Press. 173 p.

experimental design, analysis, statistics overview.

4. Agee, J. K. 1984. **Research natural areas and fire in the national park system.** In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., tech. coords. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 72-79.

landscape-level, baseline monitoring, special sites, national parks, vegetation treatments, prescribed fire, natural areas.

5. Agresti, A. 1990. **Categorical data analysis.** New York, NY: John Wiley and Sons. 558 p.

analysis, statistics overview, categorical data analysis.

6. Aguirre-Bravo, C. 1996. **North American workshop on monitoring for ecological assessment of terrestrial and aquatic ecosystems.** Gen. Tech. Rep. RM-284. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 305 p.

monitoring overviews, general book on monitoring, ecological monitoring programs, large-scale monitoring, landscape-level, ecosystem management.

7. Ahmed, J.; Bonham, C. D.; Laycock, W. A. 1983. **Comparison of techniques used for adjusting biomass estimates by double sampling**. Journal of Range Management. 36: 217-221.

Compares the ratio and regression estimator procedures for adjusting estimates and evaluates different sizes and shapes of plots.

field techniques, production, biomass, double sampling, design, plot dimensions.

8. Aigner, D. J. 1965. **An estimation procedure for range composition problems**. American Statistical Association Journal. 60: 308-319.

analysis, rangeland, community composition, statistics overview.

9. Aitken, M. 1981. **Regression models for repeated measurements**. Biometrics. 37: 831-832.

Repeated measures designs contain two sources of variation: the usual "among units" variation and the usually smaller "within unit" variation over time. The author contends that an ANOVA model, recognizing within unit variation caused by time and treatment and their interactions, is usually adequate. If the data are irregular, with different numbers of measures on different units, the analysis become much more complicated. Correlation between units, such as plots in a block, can be addressed by general maximum likelihood methods.

design, analysis, experimental design, ANOVA, repeated measures analysis.

10. Albertson, F. W.; Tomanek, G. W. 1965. **Vegetation changes during a 30-year period in grassland communities near Hays, Kansas.** Ecology. 46: 714-720.

Vegetation was studied from 1932 to 1961 in 3 common prairie communities using 8 to 12 permanent $1m^2$ quadrats in which species cover was measured by charting. Cover of dominant species changed dramatically over the thirty years, largely in response to weather patterns. Cover of *Buchloe dactyloides*, for example, was nearly 70% at the beginning of the study, declined to nearly 10%, recovered to about 65% and then declined to less than 10% in the last 5 years of the study. Cover of *Bouteloua gracilis* ranged from 20 to 70%. Some dominant species at the beginning of the study nearly disappeared by the end of the study. Similarly, some species with low cover, or absent from the plots at the beginning of the study became dominants by the end. The dramatic changes in species composition in these supposedly stable climax communities suggests the difficulty that monitoring for response to management changes entails.

community-level, ecological models, objectives, ecological processes, community composition, community structure, community change, predicting change, grassland, long-term ecological monitoring, charting, succession, canopy cover, natural variability.

11. Aldon, E. F.; Barstad, J. F. 1987. **Escudilla Mountain Research Natural Area: a study of an undisturbed montane grassland in Arizona.** Natural Areas Journal. 7(3): 107-117.

The authors conducted a detailed plant community analysis of grasslands within the Escudilla Mountain Research Natural Area in eastern Arizona, following community structure analysis methods developed by Pase (1981). Vegetation cover, frequency, density, and biomass data were collected along 2 to 4 randomly located transects in each of 3 grasslands. The labor-intensive methods consisted of collecting cover and frequency data in 100 small microplots (5x10cm) along each transect. Density data were collected in 10 of the microplots. Biomass data were collected in 0.5m diameter circular plots along a separate transect parallel with the baseline transect. Importance values, diversity indices, and biomass measurements were analyzed to provide a detailed description of grassland community structure.

special sites, general examples, design, natural areas, baseline monitoring, diversity indices, grassland, cover, frequency, density, biomass, permanent plots.

12. Aldrich, R. C. 1981. **Limits of aerial photography for multi-resource inventories**. In: Lund, H. G.; Caballero, M.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30 to December 6; LaPaz, NM. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 221-229.

Photographic scale, film, format, quality, and distortion are discussed. Use of aerial photographs for measures of cover, biomass, landform, mortality, timber volume, forage, and changes in cover class is described briefly. Required resolution, recommended film type, minimum scale, and platform are listed for various applications by vegetation type.

aerial photography, remote sensing, large-scale monitoring, cover, forest.

13. Allen, R. B. 1993. **An appraisal of monitoring studies in South Island tussock grassland, New Zealand**. New Zealand Journal of Ecology. 17: 61-63.

Monitoring is defined as the periodic remeasurement of appropriate parameters by comparable methods at fixed sample locations to detect long-term vegetation change. In a review of 56 vegetation monitoring studies in tussock grasslands, 45% were intended to monitor changes resulting from grazing management. Parameters measured included plant cover, frequency, abundance / dominance, biomass, density, population size and population structure, soil nutrient levels, and animal activity. Success was appraised based on the reporting fate of results. Of the studies employing photographs, only 36% were summarized and reported in any form. Methods using plot and transect approaches had the highest level of publication in refereed literature (42%). The author suggests that cover data measured by either line or point intercepts is the most reliable vegetative measure and is applicable to most monitoring situations. Failure to produce publishable results appeared directly related to poor objective development. The objective(s) must be clearly defined so parameters which best describe the expected change can be measured.

objectives, vegetation treatments, community composition, community structure, community change, community-level, field techniques, predicting change, grassland, density, canopy cover, biomass, frequency.

14. Allen, R. B.; Rose, A. B.; Evans, G. R. 1983. **Grassland survey manual: a permanent plot method**. FRI Bull. 43. [Publisher location unknown]: New Zealand Forest Service, Forest Research Institute. 71 p.

field techniques, design, permanent plots, grassland, general examples.

15. Allen, T. F. H.; O'Neill, R. V.; Hoekstra, T. W. 1984. **Interlevel relations in ecological research and management: some working principles for hierarchy theory**. Gen. Tech. Rep. RM-110. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 11 p.

landscape-level, scale, ecosystem management, large-scale monitoring.

16. Allen, T. H. F.; Shugart, H. H. 1983. **Ordination of simulated complex forest succession: a new test of ordination methods**. Vegetatio. 51: 141-155.

community-level, objectives, analysis, community comparisons, community change, detecting change,

predicting change, succession, ordination, multivariate analysis.

17. Ames, M. 1993. **Sequential sampling of surface-mined land to assess reclamation**. Journal of Range Management. 46: 498-500.

The federal regulatory standard for successful reclamation requires ground cover and productivity of the reclaimed area be "at least 90% of the ground cover and productivity of the reference area with 90% statistical confidence." The author points out that the statistical objective in this situation is not parameter estimation, but to prove test whether the mean cover and productivity of the reclaimed area is greater than the value that is 90% of the reference. Sample size will depend on the difference between these values. If the mean cover of the reclaimed area is much larger than the 90% value, there will be fewer samples required to show that it is larger than if the actual mean is only slightly greater than the 90% value. Sample size is thus determined by the size of the difference between the actual mean and the 90% value, and the desired power of the test. A sequential sampling approach can be used to address this issue. The author describes three (sequential probability ratio test, sequential t-tests, and Stein's method), recommends Stein's method, and gives an example of its application.

community-level, analysis, design, community composition, cover, canopy cover, biomass, production, power, precision, sample size, experimental design, sampling design, field techniques, restoration.

18. Andariese, S. W.; Covington, W. W. 1986. **Biomass estimation for four common grass species in northern Arizona ponderosa pine**. Journal of Range Management. 39: 472-473.

Eighty individuals, twenty each of four grass species, were selected to represent the range of variability in plant size and shape observed at two pondersoa pine forest sites. Three performance attributes were measured on each individual: basal area, plant height, and number of seedheads. The biomass of each individual was then measured by harvesting at ground level, drying, and weighing. A portion of the data (80%) was used to calculate the relationship between biomass and performance measures and the remainder used to test and validate the model. Plant basal area provided 81 to 87% predictive power of biomass in a log-log relationship. Seedhead number and plant height provided little improvement in the correlation. The authors suggest that basal area, rather than the traditional ocular cover estimate, would provide a better measure in double sampling approaches used to estimate production.

field techniques, grassland, cover, ocular estimation, biomass, performance, cover classes, production, heights, weight estimate, double sampling.

19. Anderson, D. 1983. **Research goals for natural areas**. Natural Areas Journal. 3: 27-32.

special sites, natural areas, objectives.

20. Anderson, D. M.; Kothmann, M. M. 1982. **A two-step sampling technique for estimating standing crop of herbaceous vegetation**. Journal of Range Management. 35: 675-677.

Standing crop was measured using a double sampling approach in which cover was estimated in a large number of plots, standing crop measured in a smaller number of plots (dried, clipped, and weighed), and the relationship between the two determined with a regression estimator. Cover was estimated in twenty-five 10x10cm subunits delineated by a wire grid within a 50x50cm plot. Cover was estimated to the nearest 1/4 unit. Biomass was measured within a subset of the same 10x10cm units. Calculations for estimating the mean standing crop, and the precision of that estimate is presented through an example. The technique is best applied to low-growing vegetation. Two observers can evaluate up to 200 plots in a day.

community-level, herbaceous species, community composition, grassland, canopy cover, ocular estimation, biomass, production, cover classes, double sampling.

21. Anderson, J. E.; Holte, K. E. 1988. **Vegetation development over 25 years without grazing on sagebrush dominated rangeland in southern Idaho**. Journal of Range Management. 34: 25-29.

general examples, community-level, shrubland, shrub, herbaceous species, long-term ecological monitoring, rangeland.

22. Anderson, M. C.; O'Farrell, M. J. 1994. **Enhancing the suitability of habitats for the endangered Stephen's kangaroo rat: a long-term experimental study**. In: Covington, W. W.; DeBano, L. F., tech. coords. Sustainable ecological systems: implementing an ecological approach to land management; 1993 July 12-15; Flagstaff, AR. Gen. Tech. Rep. RM-247. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 300-301.

This paper describes the results of the first year of a five-year study to determine the effects of three vegetation treatments on kangaroo rat habitat. The study illustrates a replicated experimental design of 2 to 12 plots per treatment. Analysis demonstrates use of box and whiskers diagrams, ANOVA, and canonical ordination.

community-level, habitat management, monitoring and management, objectives, vegetation treatments, prescribed fire, community composition, community change, design, analysis, ANOVA, ordination, experimental design, detecting change.

23. Anderson, T. W. 1984. **An introduction to multivariate statistical analysis. 2nd edition**. New York, NY: John Wiley and Sons. 675 p.

analysis, multivariate analysis, statistics overview.

24. Andrew, M. H.; Noble, I. R.; Lange, R. T.; Johnson, A. W. 1981. **The measurement of shrub forage weight- three methods compared**. Australian Rangeland Journal. 3: 74-82.
technique comparison, field techniques, shrub, production, weight estimate, canopy volume, shrubland, rangeland.

25. Andrew, M. H.; Noble, I. R.; Lange, R. T. 1979. **A non-destructive method for estimating the weight of forage on shrubs**. Australian Rangeland Journal. 1: 225-231.
field techniques, shrubland, rangeland, production, shrub.

26. Andrew, N. L.; Mapsone, B. D. 1987. **Sampling and the description of spatial pattern in marine ecology**. Oceanography and Marine Biology: An Annual Review. 25: 39-90.
Provides examples and directions for power analysis in ecological studies.
power, precision, analysis, sampling design, pattern, Type I and Type II errors.

27. Archer, S. 1989. **Have southern Texas savannas been converted to woodlands in recent history?** American Naturalist. 134: 545-561.
landscape-level, large-scale monitoring, detecting change, forest, woodland, savanna, community-level, community change.

28. Armentano, T. V. 1981. **Standardized ecological measurements in natural areas**. Natural Areas Journal. 1(2): 3-8.
This paper provides a conceptual framework for designing ecological monitoring in natural areas. The author emphasizes a focus on monitoring ecological processes as a means of assessing ecosystem changes over time. A listing of basic biological processes and suggested parameters which may be measured to monitor them is provided. The paper concludes with a discussion of various considerations in developing site-specific monitoring programs including; standardization of methods on a site, thorough documentation of methods and plot locations, and archiving of specimens. It is suggested that preserving specimens of organisms, soils, and water may be one of the most cost-effective investments of a limited program.
special sites, baseline monitoring, natural areas, specimen curation, protected areas, permanent plots, monitoring overviews, monitoring examples.

29. Armitage, P. 1955. **Tests for linear trends in proportions and frequencies**. Biometrics. 11: 375-386.
detecting change, frequency, analysis, trend analysis.

30. Armour, C. D.; Bunting, S. C.; Neuenschwander, L. F. 1984. **Fire intensity effects on the understory in ponderosa pine forests**. Journal of Range Management. 37: 44-49.
landscape-level, prescribed fire, forest, disturbance, permanent plots, canopy cover, frequency, community-level.

31. Armour, C. L.; Platts, W. S. 1983. **Field methods and statistical analyses for monitoring small salmonid streams**. FWS/OBS-83/33. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service. 200 p.
Although developed for monitoring fish habitat and populations, this publication provides useful information for development of a terrestrial plant monitoring project as well. The introduction provides an overview of monitoring in the context of management and gives guidance on the choice of monitored variables. The ecological model approach described in Chapter II can be adapted for vegetation monitoring projects. Some of the habitat measurements described in Chapter III can be used directly on terrestrial systems, and the description of calculations for summary statistics and confidence intervals, along with the examples given, may be useful as an introduction to analysis techniques. Chapter IV provides a good overview of basic statistical and sampling design concepts and Chapter V gives a number of worked examples of analyzed monitoring data.
ecological monitoring programs, general examples, adaptive management, ecological models, feedback loops, monitoring and management, objectives, analysis, statistics overview, monitoring overviews, sampling design.

32. Armour, C. L.; Williamson, S. C. 1988. **Guidance for modeling causes and effects in environmental problem solving**. Biological Rep. 89(4). Washington, DC: U.S. Department of Interior, Fish and Wildlife Service. 21 p.
This report provides guidance on development of an ecological model and consideration of potential causes and effects in complex systems. Written for field personnel in management situations, this report presents a framework for identifying potential causes of an observed effect, simplifying a number of complex causes into a theoretical model, and using teams of experts to identify the most important potential causes for effects seen within a system.
ecological monitoring programs, ecological models, monitoring and management, objectives, interdisciplinary design.

33. Arno, S. F.; Reinhardt, E. D.; Scott, J. H. 1993. **Forest structure and landscape patterns in the subalpine lodgepole pine type: a procedure for quantifying past and present conditions**. Gen. Tech. Rep. INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 17 p.
A pilot study designed to document forest structure, landscape patterns, and past fire disturbances was conducted in a lodgepole pine/subalpine fir forest on a 500 acre site in western Montana. A grid was established of thirty-five 0.1 acre circular plots, spaced 800 feet apart. Within each plot, all living trees were tallied by diameter size class and species. Dead overstory species and their diameter were listed, and their cause of death determined, if possible. Trees with fire scars were identified and the best scars sampled with a cut out cross-section. Increment borings of older fire-scarred trees and younger trees were taken. For each

point, the date of a stand-replacing fire, mixed fire or undetermined fire was determined, labeled on the grid, and visually assessed to evaluate fire disturbance and other patterns. A past comparison year was chosen (in this case 1900), and an estimated structure of each sampling point at that time assigned (species composition, diameter class). By using the percent of sampling points in each structural condition, then and now, comparisons of change in terms of percent of area were made. In this pilot study, data collection required 20 person-days of field work.

landscape-level, community-level, disturbance, ecological processes, landscape change, community composition, community structure, community change, succession, coniferous forest, DBH, tree.

34. Arno, S. F.; Simmerman, D. G.; Keane, R. E. 1986. **Characterizing succession within a forest habitat type--an approach designed for resource managers**. Res. Note INT-357. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

tree, community-level, succession, detecting change, forest, inventory, predicting change, forest, objectives, community change.

35. Arno, S. F.; Simmerman, D. G.; Keane, R. E. 1985. **Forest succession on four habitat types in western Montana**. Gen. Tech. Rep. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 74 p.

tree, community-level, succession, forest, detecting change, predicting change.

36. Arzani, H.; King, G. W. 1994. **Comparison of wheel point and point frame methods for plant cover measurement of semiarid and arid rangeland vegetation of New South Wales.** Rangeland Journal. 16: 94-105.

cover, field techniques, canopy cover, point frames, point intercept, technique comparison.

37. Arzani, H.; King, G. W. 1996. **An examination of techniques for estimating rangland production in semiaird and arid New South Wales**. In: West, N. E., ed. Rangelands in a sustainable biosphere. Proceedings of the Fifth International Rangeland Congress; 1995 July 23-28; Salt Lake City. Denver, CO: Society of Range Management: 15-16.

No significant differences were found in cover estimates completed with a wheelpoint apparatus compared to point frames. Production was accurately estimated by correlations with cover using either a double sampling approach or pooled species group equations. The dry-weight-rank method was less accurate.

cover, production, field techniques, technique comparison, canopy cover, dry-weight-rank, point intercept.

38. Ashby, E. 1935. **The quantitative analysis of vegetation.** Annals of Botany. 49: 779-802.

field techniques, analysis, vegetation sampling overview.

39. Asrar, G.; Myneni, R. B.; Kanemasu, E. T. 1989. **Estimation of plant canopy attributes from spectral reflectance measurements.** In Asrar, G., ed. Theory and applications of optical remote sensing. New York, NY: John Wiley and Sons: 252-296.

Correlation of plant canopy attributes with remotely sensed radiometric data can sometimes be misleading because different attributes may produce the same remotely sensed signal. This chapter describes some methods and applications for estimating absorbed photosynthetically active radiation, green leaf area index, above-ground phytomass, and leaf normal distribution.

remote sensing, Landsat, MSS, TM, production.

40. Atkinson, A. C.; Hunter, W. G. 1968. **The design of experiments for parameter estimation**. Technometrics. 10: 271-289.

analysis, precision, experimental design, sampling design, statistics overview, design, precision.

41. Auerbach, M.; Shmida, A. 1987. **Spatial scale and the determinants of plant species richness**. Trends In Ecology and Evolution. 2(8): 238-242.

landscape-level, community-level, species richness, scale, patch dynamics.

42. Ausmus, B. 1984. **An argument for ecosystem level monitoring.** Environmental Monitoring and Assessment. 4: 275-293.

monitoring examples, landscape-level, large-scale monitoring, integrated monitoring, ecosystem management.

43. Austin, D. D.; Urness, P. J.; Riggs, R. A. 1986. **Vegetal change in the absence of livestock grazing, mountain brush zone, Utah.** Journal of Range Management. 39(6): 514-517.

field techniques, shrub, herbaceous species, general examples, woodland, detecting change, point intercept, cover.

44. Austin, M. P. 1981. **Permanent quadrats: an interface between theory and practice.** Vegetatio. 46: 1-10.

Understanding vegetation dynamics is complicated by the large number of factors that may be affecting vegetation composition and structure: primary succession, disturbance and secondary succession, rare events, climatic fluctuation and change, and cyclic vegetation fluctuations. Further complexity is introduced by spatial variability and the persistence of "nuclear" areas of certain long-lived and clonal species in spite of changing conditions. Permanent quadrats that focus on functional characteristics (production, diversity, or biomass) provide no insight into the compositional changes associated with succession. Studies of vegetation dynamics should use contiguous permanent quadrats so spatio-temporal mosaics can be observed. These should be

replicated so changes due to local chance occurrences can be recognized.

design, community change, community-level, permanent plots, succession, objectives, predicting change, field techniques.

45. Austin, M. P. 1984. **Problems of vegetation analysis for nature conservation**. In: Myers, K.; Margules, C. R.; Musto, I., eds. Survey methods for nature conservation. Canberra, Australia: CSIRO (Commonwealth Scientific and Industrial Research Organization): 101-130.

general examples, design, field techniques, vegetation sampling overview, ecological monitoring programs, analysis.

46. Austin, M. P. 1991. **Vegetation: data collection and analysis**. In Margules C. R.; Austin M. P., eds. Nature conservation: cost effective biological surveys and data analysis. Canberra, Australia: CSIRO (Commonwealth Scientific and Industrial Research Organization): 37-41.

This chapter contains a short commentary on the collection and analysis of vegetation survey data. The author presents several questions to consider at the onset of a project. Why collect the data? Can existing data suffice? How much data must be collected? Does the value of the information justify the cost? Which analyses will extract the maximum information from the data? Emphasized is the importance of defining the purpose and use of data before they are collected. The author notes that vegetation data are expensive to collect; thus, it is important to pursue data collection in the most cost-effective manner available. He points out that existing data are often available and may be used in place of new data. The author also presents examples of simple graphical methods which he contends may be as useful as elaborate multivariate methods.

monitoring overviews, field techniques, vegetation sampling overview, analysis, objectives, inventory, multivariate analysis, graphical analysis.

47. Austin, M. P.; Heyligers, P. C. 1991. **New approach to vegetation survey design: gradsect sampling**. In Margules C. R.; Austin M. P., eds. Nature conservation: cost effective biological surveys and data analysis. Canberra, Australia: CSIRO (Commonwealth Scientific and Industrial Research Organization): 31-36.

This chapter illustrates gradsect sampling which is utilized for broad-scale vegetation surveys which describe the types and ranges of plant communities in a heterogeneous landscape. This method is based on the deliberate selection of transects that contain the steepest environmental gradients and are accessible for sampling. The authors utilize a study of plant communities along the north coast of New South Wales to illustrate this method. Gradsects in this study were selected based on a grid/cell analysis of rainfall, elevation, and rocktype information over the study area. Considering possible access routes for sampling and ensuring rare rocktypes were included, several possible locations for gradsects were reviewed. Gradsects were selected to represent the range of environmental conditions. The gradsects accounted for approximately 32% of the study area and 172 of 215 environmental cells found within the study area. The sampling design within each gradsect is explained in detail, incorporating geographical replication and a representation of the range of environmental conditions. At each sampling point, 20x50m plots were established in which all species of canopy trees were listed and the 3 most common ranked according to their abundance. Notes on understory and groundlayer were taken. The authors conclude with an outline of steps to take in executing a reasonable survey design.

design, field techniques, vegetation sampling overview, general examples, sampling design, landscape-level, pattern, inventory.

48. Austin, M. P.; Heyligers, P. C. 1989. **Vegetation survey design for conservation: gradsect sampling of forests in north-eastern New South Wales**. Biological Conservation. 50: 13-32.

The authors report on a study of forest vegetation along the north-eastern coast of New South Wales, Australia using gradsect sampling. This is an efficient method for obtaining a representative sample of the floristic variation over broad heterogeneous landscapes. The primary framework for sampling is provided by gradsects, which are broad transects selected to incorporate the maximum environmental variation within the study area. Typically, altitudinal gradients are selected which correlate with temperature and precipitation influences on vegetation. In this study, a regular grid with 1 km^2 spacing in both longitudinal and latitudinal directions was generated for the study area. For each grid point, elevation, annual means of rainfall and of daily temperatures, and geologic type were recorded. These grid data were analyzed to examine patterns of environmental variation in the study area as a basis for selecting gradsects. Additional criteria for selecting gradsects were accessibility for sampling and inclusion of rare geologic types. The 4 selected gradsects overlapped in environmental conditions, providing a degree of geographical replication. Sampling points within gradsects were selected by accessibility, and by a set of rules accounting for frequency of occurrence of environmental classes and geographic distribution. Each sampling point consisted of five 50x20m plots chosen from different topographic positions. Within each plot, all species of canopy trees were recorded and the 3 most common species ranked according to their abundance. After describing the method, the authors discuss many of the practical difficulties encountered in sampling design and data analysis. The data matrix resulting from the survey consisted of 263 species by 1025 plots. Multivariate computer classification was utilized to analyze the data. The authors conclude with a review of four principles of the overall design; deliberate selection of gradsects, adequate environmental stratification, replication, and randomization of samples where practical.

forest, design, analysis, landscape-level, general examples, sampling design, vegetation sampling overview, field techniques, pattern, design, inventory, multivariate analysis, community composition, community classification.

49. Austin, M. P.; Williams, O. B.; Belbin, L. 1981. **Grassland dynamics under sheep grazing in an Australian Mediterranean type climate.** Vegetatio. 47: 201-211.
community-level, herbaceous species, general examples, grassland.

50. Avery, T. E. 1975. **Natural resources measurement.** New York, NY: McGraw-Hill. 331 p.
This book is designed as a college textbook and reference on natural resources sampling. It is divided into three main sections. The first covers concepts germane to all types of resources: sampling, calculation of descriptive statistics, use of compass, measuring distances, field maps, and aerial photo interpretation. The second part, nearly half of the book, covers the measurement of timber resources. The third part includes several chapters describing methods specific to rangeland, wildlife, fisheries, water resources, and recreational resources.
general book on monitoring, resource management, community composition, community structure, vegetation mapping, cover, canopy cover, ocular estimation, production, biomass, crown diameter, DBH, aerial photography, density, frequency, field techniques, community-level, remote sensing, vegetation sampling overview, tree, forest.

51. Avery, T. E.; Berlin, G. L. 1992. **Fundamentals of remote sensing and airphoto interpretation.** New York, NY: MacMillan. 472 p.
This book is an update (the fifth edition) of a text originally titled "Interpretation of Aerial Photographs." This edition incorporates new information on satellite remote sensing and GIS, and thus requires a name change. The book remains, however, primarily a text on air photo interpretation. The book is marvelously attractive, with over 440 black and white photographs, including 160 stereo-pairs, and 50 color photographs. The layout and fascinating photographs make this an extremely readable textbook. Each chapter is written as a unit, including suggestions for additional reading and exercises. Of primary interest for vegetation monitoring is a chapter titled "Forestry applications" which also addresses community cover mapping from aerial photographs in non-forested types. The authors describe how individual range plants and grassland types can be identified at photo scales of 1:500 to 1:2500, and individual trees and large shrubs at 1:2500 to 1:10,000. Typical diagnostic features to identify different species are plant height, shadow, crown margin, crown shape, foliage pattern, texture, and color. For some forested areas, diagnostic keys to species identification have been developed. The bibliography includes references to these guides.
remote sensing, Landsat, AVHRR, aerial photography.

52. Avery, T. E.; Canning, J. 1973. **Tree measurements on large-scale aerial photographs.** New Zealand Journal of Forestry. 18(2): 252-264.
forest, aerial photography, remote sensing.

53. Awbrey, R. T. 1977. **Locating random points in the field.** Journal of Range Management. 30: 157-158.
A method of locating random points within a rectangular sampling area is described. Points are originally selected as xy coordinates in the sampling area using a random number table. The distance and direction from the origin is determined by converting the rectangular coordinates to polar angle and radial distance. If using a transit, the polar angle provides the direction. For a sighting compass, the angle must be translated into an azimuth.
design, field techniques, plot selection, random sampling.

54. Bailey, N. T. J. 1995. **Statistical methods in biology. 3rd ed.** New York, NY: Cambridge. 272 p.
analysis, statistics overview.

55. Bailey, R. G. 1991. **Design of ecological networks for monitoring global change.** Environmental Conservation. 18: 173-176.
global change monitoring, integrated monitoring.

56. Bailey, R. G. 1987. **Suggested hierarchy of criteria for multiscale ecosystem mapping.** Landscape and Urban Planning. 14: 313-319.
landscape-level, general examples, large-scale monitoring, scale, vegetation mapping, ecosystem management.

57. Bailey, R. G.; Jensen, M. E.; Cleland, D. T.; Bourgeron, P. S. 1994. **Design and use of ecological mapping units.** In: Jensen, M. E.; Bourgeron, P. S., eds. Ecosystem management: principles and applications. Gen. Tech. Rep. PNW-318. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 95-106.
An overview of theory, design, and use of ecological mapping units is presented in this paper. Ecological mapping units which define similar biophysical environments are useful in characterizing and monitoring ecosystems over time, especially at broader landscape scales. The authors provide several examples of the use of ecological map units in ecosystem-based management, including monitoring. Ecological unit hierarchies are used to delineate geographic patterns. These units and patterns may then be used to stratify ecosystems for inventory and monitoring purposes.
landscape-level, inventory, large-scale monitoring, vegetation mapping, pattern.

58. Baker, R. J. 1980. **Multiple comparison tests.** Canadian Journal of Plant Science. 60: 325-327.
community change, detecting change, analysis, multiple comparisons.

59. Baker, R. L.; Thomas, C. E. 1983. **A point frame for circular plots in southern forest ranges**. Journal of Range Management. 36(1): 121-123.

The authors modified the standard point frame, with its equally spaced points, to measure circular plots. Points are distributed along the sampling bar so the center is not over-sampled. Pin distances were calculated by dividing the area of the plot into 5 concentric rings of equal size, splitting these with 20 equally spaced radii, and calculating the centroid of each resulting polygon. The frame was also modified to measure vegetation up to 152cm tall.

field techniques, cover, tools, canopy cover, point frames, point intercept.

60. Baker, W. L. 1989. **A review of models of landscape change**. Landscape Ecology. 2: 111-133.

landscape-level, landscape change.

61. Baker, W. L.; Honaker, J. J.; Weisberg, P. J. 1995. **Using aerial photography and GIS to map the forest-tundra ecotone in Rocky Mountain National Park, Colorado, for global change research**. Photogrammetric Engineering and Remote Sensing. 61(3): 313-320.

The authors report on the initial phase of a study of the effects of global climate change on the forest-tundra ecotone (FTE) in Rocky Mountain National Park. Scanned aerial photography and GIS techniques were combined to map the FTE in the Park. The authors describe in detail how photography was scanned and orthorectified, and the limitations of this method. Through use of limit lines (depicting upper limits of vegetation zones) and boundary lines the authors document spatial occurrence of krummholz, patch forest, and closed forest zones. They also document natural disturbances and permanent environmental features which influence FTE patterns. The paper concludes with a discussion on future applications of this method.

remote sensing, disturbance, tree, monitoring examples, alpine, aerial photography, ecotones, national parks, global change monitoring, forest.

62. Bakker, J. P.; Olff, H.; Willems, J. H.; Zobel, M. 1996. **Why do we need permanent plots in the study of long-term vegetation dynamics?** Journal of Vegetation Science. 7: 147-156.

succession, community-level, community change, permanent plots, long-term ecological monitoring.

63. Bannister, P. 1966. **The use of subjective estimates of cover-abundance as the basis for ordination**. Journal of Ecology. 54: 665-674.

analysis, cover, community-level, ocular estimation, observer variability, ordination, multivariate analysis, community composition, cover classes, canopy cover, field techniques.

64. Barcikowski, R. S.; Robey, R. R. 1984. **Decisions in single group repeated measures analysis: statistical tests and three computer packages**. American Statistician. 38: 149-150.

In a repeated measures design, several observations are made of the same unit (such as repeat measures of a permanent monitoring plot). The design requires several decisions in analysis on the part of the investigator: 1) Which model, univariate or multivariate, is appropriate? 2) Should the univariate F-test be adjusted or unadjusted? 3) How should sphericity be tested? These are discussed and recommendations given in the context of popular statistics packages.

detecting change, analysis, repeated measures analysis, permanent plots.

65. Barkman, J. J. 1988. **A new method to determine some characters of vegetation structure**. Vegetatio. 78: 81-90.

community-level, community structure, community classification, community composition.

66. Barnthouse, L. W.; O'Neill, R. V.; Bartell, S. M.; Suter, G. W. 1986. **Population and ecosystem theory in ecological risk assessment**. Proceedings, ninth American Society for Testing and Materials symposium on aquatic toxicology and hazard assessment. Philadelphia, PA: American Society for Testing and Materials: 82-96.

community-level, landscape-level, objectives, ecological models, predicting change.

67. Barrett, E. C.; Curtis, L. F. 1992. **Introduction to environmental remote sensing. 3rd ed**. New York, NY: Chapman and Hall. 426 p.

This relatively recent textbook provides an overview of remote sensing with applications to various management problems. The first approximately 100 pages give an introduction to characteristics and sensing of radiation. Various platforms are described, including fixed wing aerial and satellite. One short chapter gives an overview of aerial photography evaluation, and another describes digital data analysis, but neither are in-depth enough for actual application. The second half of the book describes uses of remote sensing in various disciplines. Of these, only the chapter "Ecology, conservation and resource management" is applicable to vegetation monitoring. In general, this book provides a good introduction and overview of remote sensing and its applications, but lacks the detail needed to completely understand or apply any techniques.

remote sensing, aerial photography, SPOT, Landsat, MSS, AVHRR, TM, MSS.

68. Barrett, G. W. 1985. **A problem-solving approach to resource management**. Bioscience. 35: 423-427.

monitoring and management, adaptive management, objectives.

69. Barrett, J. P. 1969. **Estimating averages from point-sample data**. Journal of Forestry. 67: 185.

analysis, forest, precision, tree, field techniques, variable plots.

70. Barrett, J. P.; Goldsmith, L. 1976. **When is n sufficiently large?** American Statistician. 30(2): 67-70.

As the sample size (n) becomes sufficiently large, the confidence interval calculated based on the Student's t distribution is valid, regardless of the underlying normality or skewness of the data. How large the sample size must be depends on the distribution of the data. For data nearly normally distributed, n can be quite small, but for highly skewed data, it must be quite large. Three biological examples are used in a Monte Carlo simulation to illustrate the effect of skewness on the size of the sample needed to provide valid confidence intervals.

analysis, design, pilot study, sample size, sampling design, confidence intervals.

71. Barrett, J. P.; Guthrie, W. A. 1969. **Optimum plot sampling in estimating browse**. Journal of Wildlife Management. 33: 399-403.

production, utilization, shrub, design, plot dimensions.

72. Barrett, J. P.; Nevers, H. P. 1967. **Slope correction when point-sampling**. Journal of Forestry. 65: 206-207.

tree, design, analysis, field techniques, sampling design, forest, variable plots.

73. Barrett, S. W.; Arno, S. F. 1988. **Increment-borer methods for determining fire history in coniferous forests**. Gen. Tech. Rep. INT-244. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

landscape-level, tree-ring analysis, prescribed fire, disturbance, landscape patterns, forest, ecosystem management.

74. Bartolome, J. W.; Kosco, B. H. 1982. **Estimating browse production by deerbrush (*Ceanothus integerrimus*)**. Journal of Range Management. 35: 671-672.

Deerbrush is an important livestock and game browse species, but its open crown and drooping branches typifies a large group of species for which annual production is difficult to measure. The diameter of second order stems (those arising from the main stem) predicted leaf and branch weights with a linear regression correlation coefficient of 0.97. Prediction of leaf weight alone was slightly less robust (0.83). The authors suggest using second order stems may be more accurate than basal stem diameter for a number of shrub species.

field techniques, biomass, production, shrub, basal area.

75. Barton, J. D.; Schmelz, D. V. 1987. **Thirty years of growth records in Donaldson's Woods.** Proceedings of the Indiana Academy of Science. 96: 209-214.

monitoring examples, forest, long-term ecological monitoring, community-level, community change, succession.

76. Bartos, D. L. 1978. **Modeling plant succession in aspen ecosystems**. In: Hyder, D. N., ed. Proceedings of the 1st International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 208-211.

A systems approach was used to develop a model of ecological succession in aspen stands. The goal was to make the model realistic enough to predict outcomes of wood products, forage, water yield, and aesthetic values with an 80% probability of being within 20% of the actual value.

objectives, forest, tree, predicting change, ecosystem, ecosystem management, ecological models, succession, community-level.

77. Bartos, D. L.; Mueggler, W. F. 1982. **Early succession following clearcutting of aspen communities in northern Utah.** Journal of Range Management. 35: 764-768.

community-level, community change, disturbance, succession, forest.

78. Bartz, K. L.; Kershner, J. L.; Ramsey, R. D.; Neale, C. M. U. 1993. **Delineating riparian cover types using multispectral, airborne videography**. Proceedings of the 14th biennial workshop on color aerial photography and videography for resource monitoring; 1993 May 25-29; Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 58-67.

The videography system included 3 video cameras, a 4-band radiometer, and a thermal infrared sensor. Flight lines were about 1600ft above the ground, allowing for a pixel size on the digitized images of about 52x52cm. Two methods were used for image classification into general classes (water, herbaceous, deciduous, soil, road, shadow, mountain shrub, and coniferous). In the "unsupervised" method, the pixels were classified automatically by computer into a user-defined number of classes based on brightness data. In the "supervised" method, ground surveys were correlated to the raw spectral data to develop the classification. The first method had misclassification error rates of up to 64%, while the latter had error rates ranging from 7% to 24% (with a single high of 42%).

vegetation mapping, riparian, remote sensing, video.

79. Basanta, M.; Diaz Vizcaino, E.; Casal, M.; Morey, M. 1989. **Diversity measurements in shrubland communities of Galicia (n.w. Spain)**. Vegetatio. 82(2): 105-112.

landscape-level, community-level, species diversity, diversity indices, shrubland.

80. Baskerville, G. L. 1971. **Use of logarithmic regression in the estimation of plant biomass**. Canadian Journal of Forestry. 2: 49-53.

production, field techniques, biomass, precision, double sampling.

81. Baskin, J. M.; Baskin, C. C. 1986. **Some considerations in evaluating and monitoring populations of rare plants**

in successional environments. Natural Areas Journal. 6(3): 26-30.
monitoring overviews, objectives, succession, detecting change, rare species.

82. Batcheler, C. L. 1971. **Estimation of density from a sample of joint point and nearest neighbor distances**. Ecology. 52: 703-709.
In this method, distances are measured from sample points to the nearest member (rp) and from that plant to its nearest neighbor (rn), and from that neighbor to its nearest neighbor (rm). The first distance is used to obtain an estimate of density, while the other distances are used to correct the bias caused by uniform or contagious spatial distributions. Further complication is introduced when a limit to the distance searched for the next individual is imposed (truncation). Ten simulated populations of 400 individuals with spatial distributions of random, uniform, and 5 different clustering formats were sampled. The effects of truncating distance and the impact of different spatial distributions are shown in a series of figures. Random populations were well estimated, uniform ones were overestimated, and contagious ones were underestimated by the sample point to nearest neighbor distance. Using $\Sigma rp/\Sigma rn$ as a correction factor for most populations, and $\Sigma rp/\Sigma rm$ for populations with secondary contagion (clusters within clusters), provided good estimates of the true density. The author claims that this method overcomes bias problems inherent in plotless methods better than the other two options, the wandering quarter method (Catana 1963) or Morista's method (Morista 1957).
field techniques, distance methods, nearest neighbor, plotless methods, wandering quarter, density, technique comparison.

83. Batcheler, C. L. 1973. **Estimating density and dispersion from truncated or unrestricted joint point-distance nearest-neighbor distances**. Proceedings of the New Zealand Ecological Society. 20: 131-147.
This paper describes the search for a method of adjusting density estimates from distance measures (sample points to nearest plant) to avoid the overestimation that occurs in uniformly spaced populations and the underestimation that occurs in spatially clumped populations. The bias is inversely related to a ratio that can be developed based on the distance from the sampling point to the nearest plant and from that plant to its nearest neighbors. A number of approaches are tested in this paper, the best of which is more completely described in an earlier paper (Batcheler 1971).
field techniques, plotless methods, density, distance methods, nearest neighbor, point-center methods, technique comparison.

84. Bates, D. M.; Watts, D. G. 1988. **Nonlinear regression analysis: its applications**. New York, NY: John Wiley and Sons. 365 p.
analysis, statistics overview.

85. Battles, J. J.; Dushoff, J. G.; Fahey, T. J. 1996. **Line intercept sampling of forest canopy gaps**. Forest Science. 42(2): 131-138.
community composition, forest, community-level, cover, line intercept, disturbance.

86. Bauer, H. L. 1943. **The statistical analysis of chaparral and other plant communities by means of transect samples**. Ecology. 24: 45-60.
Artificial populations of circles of known sizes were used to evaluate line transects for estimating "numerical abundance" (the relative number of each type of circle touching the line), and "frequency" (the relative proportions of transects contacted by the various types of circles).
technique comparison, line intercept, frequency, density, field techniques.

87. Beasom, S. L.; Haucke, H. 1975. **A comparison of four distance sampling techniques in south Texas live oak mottes**. Journal of Range Management. 28: 142-144.
Estimates from four distance sampling techniques (nearest neighbor, point-center quarter, random pairs and closest individual) were compared to actual counts of live oaks. Point-center quarter and random pairs methods gave the most accurate estimates. Both closest individual and nearest neighbor gave overestimates. All methods overestimated the relative frequency of rare species. The point-center quarter gave the most consistently accurate results, but the point-center quarter method had an advantage in this study because the same number of sampling points was used for each method, resulting in 4 distances measured at each sampling point for the point-center quarter method, 2 distances for random pairs and nearest neighbor methods, and only 1 distance for closest individual.
field techniques, plotless methods, random pairs, point-center methods, nearest neighbor, density, tree, woodland, forest, technique comparison.

88. Beck, R. F.; Tober, D. A. **Vegetational changes on creosotebush sites after removal of shrubs, cattle and rabbits**. Agric. Exp. Stn. Bull. 717. Las Cruces, NM: New Mexico State University. 22 p.
community-level, shrub, detecting change, experimental design, design, analysis, community change, shrubland.

89. Becker, D. A.; Crockett, J. J. 1973. **Evaluation of sampling techniques on tall grass prairie**. Journal of Range Management. 26(1): 61-67.
The percent composition measured by counting all shoots in 1.2x5m macroplots in a tall-grass prairie was compared to that estimated for the same macroplot by the following methods: point frames (10 points, both canopy and basal), quadrats (10x10cm), belt transects (1x0.1m long), and the point-center quarter (PCQ), angle order (AO), and wandering quarter (WQ) distance methods. All methods were employed until at least 400 shoots were encountered in each sample. All methods underestimated the percent composition of a

densely clumped species, but PCQ gave exceptionally low estimates. All of the methods except the quadrat method overestimated the relative density of a single stalked species, the PCQ method especially so. Quadrats and belt transects in general provided the best estimates, although all of the methods performed fairly well if one strongly aggregated species was eliminated from consideration. Belt transects, quadrats, and the AO (calculated by ignoring distances of <1cm) provided estimates of total density similar to actual counts. The time required to encounter 400 shoots was, in increasing order: quadrat, PCQ, WQ, AO, belt transect, and point transect.

field techniques, community-level, community composition, meadow, grassland, plotless methods, density, distance methods, nearest neighbor, point-center methods, wandering quarter, point frames, angle-order, technique comparison.

90. Belbin, L. 1992. **Comparing two sets of community data: a method for testing reserve adequacy**. Australian Journal of Ecology. 17: 255-262.

Testing whether an existing reserve system captures all of the communities or whether increasing the boundaries adds protected community types requires the comparison of one set of community data samples to another. Similarly, in a monitoring scenario, a baseline community sample is compared to a more recent one. A common approach is to use multivariate classifications of either the two data sets together or separately, but this is an indirect way to address the real issue of whether new observations can be allocated to existing classes. The author also rejects discriminant analysis (DA), the traditional method for testing the similarity of an observation with existing group observations, because of three assumptions of DA that are often violated: 1) the dispersion of the data around the group mean is assumed to be due to sampling errors, when in fact it represents real differences along a vegetation continuum; 2) species are assumed to have a linear response to environmental gradients, when in fact most species have a unimodal response shape; 3) existing groups are assumed to be the universe so creation of new groups is not possible. The author recommends an alternate approach in which the existing data, either as individual samples or in reduced form as group centroids, be compared by use of resemblance functions such as the Czekanowski, Kulczynski, Bray-Curtis, and relative Manhattan similarity/distance measures. A predetermined cut-off value of one of these coefficients would determine if a new data point belonged within a currently defined group, or represented a new group. Alternately, the boundary around a group centroid (defined in one of several ways) can be used as the minimum distance between the new sampling point and the group. This approach was tested on 876 forest vegetation survey sampling points, 265 of which were in a reserve status. The approach identified nine groups not found within the existing reserve system.

special sites, community-level, landscape-level, biodiversity, landscape planning, regional planning, community composition, community classification, community change, multivariate analysis, similarity measures.

91. Bell, J. F. 1983. **Development and evaluation of methods to monitor change on national forests**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1993 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 251-254.

Change vector analysis relies on the comparison of greenness and brightness characteristics of Landsat data to monitor changes caused by management. Although this method appears to have potential for detecting major changes such as clearcuts, some types of changes that occurred on the test landscapes (mostly understory manipulations) were not detectable. Areas of sagebrush/grass also registered as high change areas because of differences in annual herbaceous production. High altitude photography was interpreted both manually and by an automatic computer-controlled digital image analysis and display system. The latter had trouble separating natural variability of aspen from real changes.

Landsat, MSS, aerial photography, remote sensing, forest.

92. Belsky, A. J. 1985. **Long-term vegetation monitoring in the Serengeti National Park, Tanzania**. Journal of Applied Ecology. 22: 449-460.

community-level, special sites, community change, national parks, long-term ecological monitoring, monitoring examples.

93. Bender, E. A.; Case, T. J.; Gilpin, M. E. 1984. **Perturbation experiments in community ecology: theory and practice.** Ecology. 65: 1-13.

landscape-level, community-level, disturbance, large-scale monitoring, detecting change, predicting change, ecological models, community change.

94. Bensom, R. E. 1983. **Using photos to extend resource inventory data.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; August 15-19, 1983; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 349-352.

The author proposes that the potential value of photographs to extend quantitative information and meet unanticipated needs is underappreciated, and that photographic information should be a standard part of all inventory and monitoring data collection. Scenic quality, wildlife habitat, fuel loading, recreation impacts, and long-term landscape change can all be evaluated and monitored with photographs. The author suggests several orientations (e.g., canopy, horizontal, and ground) taken from the same photopoint are more effective than a single frame.

field techniques, photopoints.

95. Bentley, J. R.; Seegrist, D. W.; Blakeman, D. A. 1970. **A technique for sampling low shrub vegetation by crown**

volume classes. Res. Note PSW-215. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 11 p.

Crown volume was used to measure the response of shrub vegetation to herbicide treatment. Crown volume was estimated into 12 classes based on height and diameter curves. The class breadth was narrowest for smaller shrubs because these were the most numerous. After an initial training period, most individual shrubs could be visually estimated, although borderline individuals had to be measured. A figure illustrates how height and diameter were visualized for irregular shrubs. Consistency between observers was good. Mean crown volume was calculated using the midpoint of each class. The correlation coefficient between mean crown volume estimated in classes with actual measured crown volume was 0.999. Sampling was completed in 2x2m plots, 350 to 500 of which could be done per person-day. For most of the treatment areas, 100 plots were found to provide an adequately precise sample. Estimated crown volumes were also compared to the dry weights of crowns of 4 species, measured on 10 to 20 individuals in each volume class. Correlations were all over 93%.

field techniques, community composition, community change, shrubland, crown diameter, biomass, heights, weight estimate, observer variability, ocular estimation, shrub, production, community-level, canopy volume.

96. Berger, A. R. 1992. **A special role of parks and protected areas in long-term environmental monitoring**. In Willison J. H. M.; Bondrup-Nielsen S.; Dyrsdale C.; Herman T. B.; Munro N. W. P.; Pollock. T. L., eds. Science and the management of protected areas. New York, NY: Elsevier: 385-390.

special sites, national parks, long-term ecological monitoring, monitoring overviews, objectives.

97. Berger, J. O.; Berry, D. A. 1989. **Statistical analysis and the illusion of objectivity**. American Scientist. 76: 159-165.

analysis, biological significance, statistical interpretation.

98. Berger, J. O.; Selke, T. 1987. **Testing a point null hypothesis: the irreconcilability of p values and evidence**. Journal of The American Statistical Association. 82: 112-122.

analysis, precision, statistical interpretation.

99. Bergeron, Y.; Dubuc, M. 1989. **Succession in the southern part of the Canadian boreal forest**. Vegetatio. 59: 51-63.

tree, community-level, community change, coniferous forest, forest, succession.

100. Berkelmans, R. 1992. **Video photography: a quantitative sampling method**. Reef Research. 2: 10-11.

video, field techniques.

101. Berkowitz, A. R.; Kolosa, K.; Peters, R. H.; Pickett, S. T. A. 1989. **How far in space and time can the results from a single long-term study be extrapolated?** In: Likens, G. E., ed. Long-term studies in ecology: approaches and alternatives. New York: Springer-Verlag: 192-198.

long-term ecological monitoring, biological significance, monitoring and management, ecosystem management.

102. Bernes, C.; Giege, B.; Johannson, K.; Larson, J. E. 1986. **Design of an integrated monitoring programme in Sweden**. Environmental Monitoring and Assessment. 6: 113-126.

design, monitoring examples, integrated monitoring, objectives.

103. Bernstein, B. B.; Smith, R. 1986. **Community approaches to monitoring. Institute of Electrical and Electronic Engineers Oceans 1986 conference proceedings**. Washington, DC: Marine Technology Society / Institute of Electrical and Electronic Engineers: 934-939.

community-level, community change, monitoring examples, monitoring overviews.

104. Bernstein, B. B.; Zalinski, J. 1983. **An optimal sampling design and power tests for environmental biologists**. Journal of Environmental Sciences. 16: 35-43.

The authors contend that monitoring programs should be designed to detect a predicted change of a certain magnitude with a desired level of confidence. Without careful design, monitoring programs may be underpowered (unable to detect the level of change expected) or over-replicated, with a concomitant waste of monitoring resources. The authors essentially describe a BACI design (although it is not termed that here) in which the difference between impact and control locations, averaged over the before-impact period, is compared to the difference averaged over the after-impact period. Increasing the number of sampled differences increases the power of the test, as does increasing the number of replicate pairs. Methods for determining the optimum allocation of sampling between these two levels of replication and for estimating the power of this design are described.

design, analysis, monitoring overviews, BACI, experimental design, sampling design, objectives, detecting change, power, precision.

105. Bernstein, B. B.; Zalinski, J. 1986. **A philosophy for effective monitoring. Institute of Electrical and Electronic Engineers Oceans 1986 conference proceedings**. Washington, DC: Marine Technology Society / Institute of Electrical and Electronic Engineers: 1024-1029.

monitoring overviews, objectives.

106. Berryman, D.; Bobee, B.; Cluis, D.; Haemmerli, J. 1988. **Nonparametric tests for trend detection in water quality time series**. Water Resources Bulletin. 24: 545-556.

analysis, time series, trend analysis.

107. Bigwood, D. W.; Inouye, D. W. 1988. **Spatial pattern analysis of seed banks: an improved method and optimized sampling.** Ecology. 69: 497-507.

seedbank, sampling design, design.

108. Binot, J. M.; Pothier, D.; Lebel, J. 1995. **Comparison of relative accuracy and time requirement between the caliper, the diameter tape, and an electronic tree measuring fork.** Forestry Chronicle. 71: 197-200.

field techniques, technique comparison, DBH, tree, tools.

109. Biondi, F. 1996. **Decadal-scale dynamics at the Gus Pearson Natural Area: evidence for inverse (a)symmetric competition?** Canadian Journal of Forest Research. 26(8): 1397-1406.

Individual tree growth, mortality, and establishment has been measured every decade since the permanent 400x800m plot was established in 1908. Data are used to compare growth rates by size class, and infer mechanisms of competition.

permanent plots, monitoring examples, long-term ecological monitoring, demographic techniques, tree, special sites, natural areas.

110. Biondini, M. E.; Bonham, C. D.; Redente, E. F. 1985. **Secondary successional patterns in a sagebrush (*Artemisia tridentata*) community as they relate to soil disturbance and soil biological activity**. Vegetatio. 60: 25-36.

Four levels of soil disturbance were studied on a sagebrush/ bunchgrass site: 1) mechanical removal of vegetation; 2) mechanical removal of vegetation and scarification to a depth of 30cm; 3) removal, mixture and replacement of topsoil and subsoil to a depth of 1m; and 4) subsoil placed over topsoil. The experiment utilized a randomized block design with two replications per treatment. Plots were 6x8m. Vegetation cover was measured over 6 years in ten 25x100cm permanent plots randomly located in each treatment plot. Multi-response permutation procedures (MRPP) were used to analyze species composition, rate of successional change, and soil characteristics. An appendix describes MRPP with a simple example.

community-level, cover, design, analysis, community composition, community structure, community change, predicting change, succession, shrub grassland, canopy cover, multivariate analysis, experimental design, soils.

111. Biondini, M. W.; Lauenroth, W. K.; Sala, O. E. 1991. **Correcting estimates of net primary production: are we overestimating plant production in rangelands?** Journal of Range Management. 44: 194-198.

Overestimation of net primary production (NPP) can be as much as 700% due to an accumulation of random errors associated with estimates made at intervals throughout the growing season. This is due to the truncation of estimates at zero. Even though the true mean is greater than zero, when sampling, by chance one could get a negative value (less than the previous measurement). Rather than consider this a negative value, however, most investigators consider it zero (no production). Thus the sampling distribution of positive values estimated from sampling is a truncated normal distribution rather than a true normal distribution. Two examples and corrective calculations are provided to illustrate the problem and some solutions. This issue in not only germane to monitoring using NPP, but to any monitoring situation in which negative values are treated as zeros.

field techniques, design, analysis, biomass, production, sampling design, precision.

112. Birdsey, R. A. 1995. **A brief history of the "straddler plot" debates**. Forest Science Monograph 31, Supplement. 41(3): 7-11.

This paper introduces a special monograph on the "Techniques for forest surveys when cluster plots straddle two or more conditions," a collection of four technical papers on this issue. This introduction describes the history of forest inventory sampling in the U.S., and the development of the standard ten point cluster technique. The problem of straddling clusters and the history of the debate is summarized.

design, forest, cluster sampling, inventory.

113. Birdsey, R. A. 1983. **Plot configurations for monitoring secondary forest regeneration in Puerto Rico**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 383-385.

The author suggests that several general factors should be initially considered in design: 1) for sampling in relatively inaccessible areas it is more efficient to increase the time per location and reduce the locations; 2) increasing plot size for a given number of sampling units increases the precision; 3) the coefficient of variation is less for a cluster of plots than for a single plot of the same combined area; 4) small plots are subject to high error due to the number of borderline trees. Six sub-plot cluster configurations were compared: 1 to 3 plots of either large ($40m^2$) or small ($15m^2$) size, either 25m or 50m apart. The most efficient method for estimating basal area of common species was one large and two satellite small plots, but this configuration was less effective for some other measurements. Two widely spaced plots tended to have higher errors than other configurations because of the dramatic vegetational changes that could occur within 50m.

design, cluster sampling, sampling design, sample size, precision, coniferous forest, deciduous forest, tree.

114. Bjornsson, H. 1978. **Analysis of a series of long-term grassland experiments with autocorrelated errors**. Biometrics. 34: 645-651.

analysis, trend analysis, time series, long-term ecological monitoring.

115. Blackwood, L. G. 1991. **Assurance levels of standard sample size formulas**. Environmental Science and Technology. 25(8): 1366-1367.

The author differentiates between confidence levels and assurance levels. The former is the probability that an estimated values lies within a certain interval (e.g. a 95% confidence that the estimate is within 5 units of the true value); the latter is concerned with the width of the interval (e.g. ±5 units). The probability that the confidence interval will be the desired width is the assurance level. In a simulation using the sample size recommended by standard sample size formulas, in 43% of the 1000 runs the confidence interval width was greater than the desired value. The standard formulas underestimated the number of samples needed to attain the desired precision nearly half of the time.

design, analysis, confidence intervals, sample size, experimental design, precision, sampling design.

116. Blankenship, J.; Smith, D. 1966. **Indirect estimation of standing crop**. Journal of Range Management. 19: 74-77.

field techniques, production.

117. Bloom, S. A. 1980. **Multivariate quantification of community recovery**. In: Cairns, J., ed. The recovery process in damaged ecosystems. Ann Arbor, MI: Ann Arbor Science: 141-151.

A method is described that compares multi-species pre- and post-perturbation samples. The pre-perturbation samples are subjected to ordination. The ordination space occupied by the samples (three-dimensional can be visualized) can be defined in terms of all points within that space that are statistically indistinguishable (for a set alpha level, say 0.05). If the variance between pre-perturbation samples is low, then the volume of space will be small, thus the number of pre-perturbation sampling units is important. The distance between a single post-perturbation sample and the sphere of the acceptance zone created by the pre-perturbation samples can be calculated and considered the distance to recovery.

analysis, community-level, ordination, predicting change, community composition, community change, multivariate analysis, design, detecting change.

118. Bloom, S. A. 1981. **Similarity indices in community studies: potential pitfalls**. Marine Ecology Progress Series. 5: 125-128.

landscape-level, community-level, similarity measures, species lists, community comparisons, ordination, multivariate analysis, analysis.

119. Blyth, K. 1982. **On robust distance-based density estimators**. Biometrics. 38: 127-135.

A density method robust to population aggregation is described. The T-square method involves a measure of the distance between the random point and the nearest plant, and then from that plant to its nearest neighbor in the half plane perpendicular to the first distance line.

field techniques, distance methods, density.

120. Bodansky, D. 1991. **Law: scientific uncertainty and the precautionary principle**. Environment. 33: 4-5, 43-44.

statistical interpretation, monitoring and management.

121. Bohnsack, J. A. 1979. **Photographic quantitative sampling of hard-bottom benthic communities**. Bulletin of Marine Science. 29: 242-252.

field techniques, cover, canopy cover, photoplots.

122. Bonham, C. D. 1989. **Measurements for terrestrial vegetation**. New York, NY: John Wiley and Sons. 338 p.

This book is the standard reference for vegetation sampling techniques: density, cover, frequency, and production. Nearly all field techniques that have been used, including older ones now rarely employed, are covered at length in this book. Comparisons of techniques are included.

vegetation sampling overview, community composition, vegetation mapping, density, cover, frequency, production, biomass, utilization, technique comparison, tools, field techniques.

123. Bonham, C. D.; Larson, L. L.; Morrison, A. 1980. **A survey of techniques for measurement of herbaceous and shrub production, cover and diversity on coal lands in the west**. Contract 17090435. Denver, CO: Office of Surface Mining, Region V. 182 p.

vegetation sampling overview, density, cover, frequency, field techniques, diversity indices, herbaceous species, shrub, shrub grassland, technique comparison.

124. Bonner, W. J.; Morgart, J. 1981. **Landsat: a sampling frame for arid land inventories**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 230-239.

A project area in northwestern Arizona was used to test Landsat MSS data in combination with other data for natural resource inventory. Landsat data were used to map land cover into 9 general classes (cold desert shrub, grassland, coniferous forest, etc.). Wooded classes were subsampled with large-scale aerial photography. Non-wooded areas were sampled with 13x15m ground plots in which cover (point intercept), shrub characteristics, and standing crop were measured.

landscape-level, general examples, pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, aerial photography, point intercept, cover, standing crop, remote sensing, inventory, field techniques.

125. Bonnor, G. M. 1972. **Forest sampling and inventories: a bibliography**. Ottawa: Forest Management Institute. 27 p.

forest, tree, vegetation sampling overview, inventory, sampling design, design, field techniques.

126. Booth, G. D. 1990. **Monitoring data and the risks of management decisions.** Monitoring and evaluation of fish, sensitive plants and wildlife: a national workshop for Forest Plan implementation; 1990 June 5-7; Park City, UT. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: [irregular pagination].

This paper discusses several important points for monitoring and management. It clearly and simply describes Type I and Type II (false change and missed change) errors and the management implications of both. It describes the importance of setting objectives and choosing measurable attributes that answer the ecological and management questions. The difference between the true value in a population and the estimated value in a sample is described, and the importance of understanding the precision of the estimate stressed. In summary, the author recommends "it may be better to do no monitoring than to do inadequate monitoring" because the latter leads to a false sense of security, is a misuse of funding, and reduces the chances of getting adequate funding to do the job right.

monitoring and management, objectives, power, precision, Type I and Type II errors, analysis, statistical interpretation, design.

127. Booth, G. D. 1984. **Some statistical aspects of baseline monitoring in research natural areas.** In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., coordinators. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 46-49.

Two analytical techniques, the CUSUM chart and the periodogram, are described as applicable to issues in Research Natural Areas. The CUSUM chart is a simple graphical technique that graphs the cumulative departures from a target. If the system is exhibiting variability around a constant mean, positive and negative values should cancel, and the cumulative sum remain near zero. If there is a directional change, the sum will steadily depart from the zero line. The periodogram is another graphical technique that shows the frequencies of cycles of various lengths in a time series data set.

analysis, trend analysis, time series, graphical analysis, baseline monitoring, special sites, natural areas.

128. Borcard, D.; Legendre, P.; Drapeau, P. 1992. **Partialling out the spatial component of ecological variation.** Ecology. 73: 1045-1055.

Variation in species abundance patterns can be attributed to four components: 1) spatial; 2) environmental (independent biotic or abiotic factors affecting species distribution); 3) spatially structured environmental variables; and 4) an unexplained residual component. The problem with the third component is that techniques that examine a spatial component and an environmental component separately extract the common spatial structuring twice, thus the analyses are partially redundant. What is needed is a method for identifying each component separately. The authors propose a method using partial canonical ordination (redundancy analysis for data where species response is linear and canonical correspondence analysis for unimodal responses) of the species and spatial matrices while controlling for the effect of the environmental descriptors. This is accompanied by a similar analysis of the species and environmental descriptors while controlling for the effect of space. Together, these two analyses provide the spatial and environmental components. The method is illustrated by testing on three examples: distribution of oribatid mites, forest vegetation, and lagoon bacteria. The method requires that the spatial relationship of the sampling units be known, in most cases by using some systematic sampling strategy.

analysis, community-level, community composition, community change, multivariate analysis, gradient analysis, ordination.

129. Bormann, G. E. 1953. **The statistical efficiency of sample plot size and shape in forest ecology**. Ecology. 34: 474-487.

All trees in an area 140x140m were censused and measured for DBH in 2x2m plots. These plots were then reconfigured by grouping into various sizes and shapes. The comparative efficiency of the various plot configurations was based on the variance of the sample, but there was no consideration of field sampling time costs. Similar to other studies reviewed by the author, rectangular plots were more efficient than square ones, but large increases in efficiency with increasing length to width ratio only occurred when the plots were placed perpendicular to the observed topographic contour and soil banding. Efficiency also increased as size of plot increased. Of the five configurations that sampled less than 15% of the area but gave acceptably precise estimates, all contained 200m² area or more. None of the sampling designs, however, provided good estimates of rare elements in the stand.

tree, design, density, DBH, precision, forest, plot dimensions, sampling design, field techniques.

130. Botkin, D. B. 1977. **Long-term ecological measurements.** Washington, DC: National Science Foundation. 44 p.

long-term ecological monitoring, monitoring overviews, monitoring examples, general book on monitoring.

131. Botkin, D. B. 1978. **A pilot program for long-term observations and study of ecosystems in the United States.** Washington, DC: National Science Foundation.

monitoring examples, long-term ecological monitoring, ecosystem management, large-scale monitoring.

132. Bourdeau, P. F. 1953. **A test of random versus systematic ecological sampling**. Ecology. 34: 499-512.

Systematic, simple random and stratified random sampling were compared in a 140x140m area in which all trees had been measured in all 4900 2x2m square sampling units (see

also Bormann 1953). A 10x10m quadrat was used to sample at varying sampling intensities of 3 to 36 sampling units. Systematic sampling in over half of the sampling schemes was slightly more efficient (smaller variance) compared to random or stratified sampling. It was also slightly more accurate (closer to the true value). These benefits were small, however, for the overall loss in efficiency of stratified random compared to systematic was only about 6.6%. The authors suggest that the possibility of increased accuracy of systematic sampling does not outweigh the benefit of statistically assessing the sampling error allowed by random sampling.

design, plot selection, precision, random sampling, systematic sampling, stratified sampling, sampling design, forest.

133. Bourgeron, P. S.; Humphries, H. C.; Jensen, M. E. 1994. **General sampling design considerations for landscape evaluation**. In: Jensen, M. E.; Bourgeron, P. S., eds. Ecosystem management, principles and applications. Gen. Tech. Rep. PNW-318. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 109-120.

The authors present a good overview of considerations in planning and conducting landscape-level evaluation and characterization work at regional scales. They review various steps and provide a set of guidelines for landscape analysis including: clarification of purpose of analysis, use of existing data, sampling design and efficiency, and use of models for interpolation and extrapolation. The two-stage gradsect sampling design is offered as an efficient means of sampling the full range of environmental variability in the landscapes being assessed. This method is discussed in detail, as is an example of its application at the Gray Ranch in southern New Mexico.

landscape-level, design, general examples, monitoring overviews, pattern, sampling design, large-scale monitoring, landscape change.

134. Bowers, F. E.; Webb, R. H.; Rondeau, R. J. 1995. **Longevity, recruitment and mortality of desert plants in Grand Canyon, Arizona**. Journal of Vegetation Science. 6: 551-564.

Old photographs were re-taken to assess the survival of individual plants visible in the photographs.

field techniques, photopoints, demographic techniques.

135. Box, G. E. P.; Jenkins, G. M. 1976. **Time series analysis, forecasting and control. Revised edition**. San Francisco: Holden-Day. 575 p.

This is one of the standard texts on time-series analysis.

analysis, time series, trend analysis, statistics overview.

136. Boyle, T. P.; Sebaugh, J.; Robinson-Wilson, E. 1984. **A hierarchial approach to the measurement of changes in community structure induced by environmental stress**. Journal of Testing and Evaluation. 12: 241-245.

community-level, analysis, community change, similarity measures, multivariate analysis.

137. Bradbury, R. H.; Hammond, L. S.; Reichelt, R. E.; Young, P. C. 1983. **Prediction versus explanation in environmental impact assessment**. Search. 14: 323-325.

statistical interpretation, analysis, monitoring and management, objectives.

138. Bradshaw, M. E. 1981. **Monitoring grassland plants in upper Teasdale, England**. In: Synge, H., ed. The biological aspects of rare plant conservation. Chichester: John Wiley: 241-257.

vegetation sampling overview, monitoring overviews, field techniques, herbaceous species, grassland, rare species, community composition, monitoring examples.

139. Brady, W. W.; Cook, J. W.; Aldon, E. F. 1991. **A microplot method for updating loop frequency range trend data: theoretical considerations and a computer simulation**. Res. Pap. RM-295. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 19 p.

Data from 3/4 inch loop measurements were originally considered an index of cover, but they actually constitute a frequency measure since the loop has area. This publication provides a methodology for estimating basal area from 3/4 inch loop data.

field techniques, technique comparison, cover, community-level, community composition, grassland, rangeland, basal area, loop frames, frequency.

140. Brady, W. W.; Mitchell, J. E.; Bonham, C. D.; Cook, J. W. 1995. **Assessing the power of the point-line transect to monitor changes in basal plant cover**. Journal of Range Management. 48: 187-190.

The authors state that "monitoring designs should clearly specify what constitutes an ecologically important vegetation change, and monitoring methods must be selected so that changes of this magnitude can be observed with acceptable error rates." Good monitoring programs are stable (an acceptable Type I error rate), powerful (an acceptable likelihood of detecting change and low Type II error rate), robust (not susceptible to extraneous factors), and cost-effective. A computer-simulated community of short-grass prairie with a single dominant species was created. Initial cover was 12%, and the community was sampled using a 100m transect along which point intercepts were measured at 1m intervals. With a single transect, a change in cover from 12% to 6% would be detected only 42% of the time. With 3 transects, such a decrease could be detected 90% of the time. Ten transects would detect a change from 12% to 10% with only a 40% probability. Power curves which demonstrate the power rating for a given Type I error rate, effect size (change in percent cover), and number of transects are useful in assessing tradeoffs in error rates and the cost of number of sampling units.

community-level, design, community composition, community change, grassland, basal area, point intercept, power, precision, detecting change, sample size, analysis, cover, rangeland, grassland.

141. Brady, W. W.; Stromberg, M. R.; Aldon, E. F.; Bonham, C. D.; Henry, S. H. 1989. **Response of a semidesert grassland to 16 years of rest from grazing.** Journal of Range Management. 42(4): 284-288.
herbaceous species, community-level, grassland, general examples, permanent plots, detecting change, canopy cover, community comparisons, natural areas, special sites, field techniques.

142. Brakenhielm, S. 1988. **Vegetation and air pollution. Spatial and temporal aspects of sampling in environmental monitoring.** Statistical Journal of The United Nations ECE. 5: 239-247.
This paper describes the vegetation subprogram of the permanent Swedish Environmental Monitoring Programme. An overview of the objectives and methods is provided.
monitoring examples, long-term ecological monitoring, integrated monitoring.

143. Bransbury, D. I.; Tainton, N. M. 1977. **The disc pasture meter: possible applications in grazing management.** Proceedings of The Grassland Society of Southern Africa. 5: 115-118.
field techniques, grassland, production, herbaceous species.

144. Bratton, S. P. 1989. **Environmental monitoring in wilderness.** Wilderness benchmark 1988: proceedings of the national wilderness colloquium; 1988 January 13-14; Tampa, FL. Gen. Tech. Rep. SE-51. Ashville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 103-112.
monitoring overviews, monitoring and management, monitoring examples, wilderness, special sites, landscape-level, large-scale monitoring.

145. Brennenman, J. 1989. **Long-term ecological research in the United States. A network of research sites.** Seattle, WA: College of Forestry Resources, University of Washington.
This report summarizes the network of long-term ecological research sites (LTER) administered through the National Science Foundation's Division of Biotic Systems and Resources. Current research conducted at each site is described.
monitoring examples, long-term ecological monitoring, integrated monitoring, baseline monitoring.

146. Brewer, L.; Berrier, D. 1984. **Photographic techniques for monitoring resource change at backcountry sites.** Gen. Tech. Rep. NE-86. Dover, DE: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 13 p.
field techniques, photopoints, photoplots, detecting change, wilderness, special sites.

147. Brewer, R. 1980. **A half-century of changes in the herb layer of a climax deciduous forest in Michigan.** Journal of Ecology. 68: 823-232.
long-term ecological monitoring, succession, community change, community-level, monitoring examples, herbaceous species, forest, deciduous forest.

148. Bricknell, J. E. 1970. **More on diameter tape and calipers.** Journal of Forestry. 68: 169-170.
tree, field techniques, tools, forest.

149. Bromberg, S. M. 1990. **Identifying ecological indicators: an environmental monitoring and assessment program.** Journal of The Air Waste Management Association. 40(7): 976-978.
landscape-level, indicators, integrated monitoring, monitoring examples.

150. Brooks, M. A. 1995. **Evaluating roadside revegetation in central Arizona.** In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 68-73.
To evaluate the success of roadside revegetation efforts, vegetation was sampled in 55 road cut and fill sites on 7 road reconstruction projects. Cover of vegetation was estimated and number of plants counted in square quadrats (50x50cm and 1x1m) placed at 2m intervals along randomly located 50m transects. Shrubs were counted in 1x50m belt quadrats. The visual appearance of the revegetation efforts was assessed by averaging a categorical classification (unsatisfactory to satisfactory) assigned by viewers.
general examples, objectives, disturbance, vegetation treatments, restoration, field techniques, cover, density, herbaceous species, shrub.

151. Brooks, R. T.; Porter, W. F. 1983. **Development of a procedure to establish conditions and monitor changes in regional wildlife habitat quality.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 223-226.
Land cover patterns were proposed as an effective measure of habitat values on a regional scale. Because these data are often updated on an annual or regular basis, they could provide an inexpensive monitoring tool if well correlated with habitat values. Land cover was quantified in terms of percent acres within a county. Multivariate analysis was used to evaluate the effect of land cover percentages on the

abundances of 24 species of birds, based on the annual breeding bird survey. This relatively simple approach was found to be a poor predictor of breeding bird abundance, but the authors suggest that adding information on the spatial configuration of the different land cover types would improve the model.

landscape-level, analysis, habitat management, landscape planning, landscape change, pattern, regional planning, multivariate analysis.

152. Bros, W. E.; Cowell, B. C. 1987. **A technique for optimizing sample size (replication)**. Journal of Experimental Marine Biology and Ecology. 114: 63-71.

analysis, design, replication, sample size, sampling design, power.

153. Brouwer, F.; Nijkamp, P. 1987. **A satellite design for integrated regional environmental modelling**. Ecological Modelling. 35: 137-148.

remote sensing, Landsat, integrated monitoring, large-scale monitoring, general examples, landscape-level.

154. Brower, J. E.; Zar, J. H. 1990. **Field and laboratory methods for general ecology. 3rd ed.** Debuque, IA: Wm. C. Brown Publishers. 237 p.

vegetation sampling overview, field techniques, technique comparison.

155. Brown, D. 1954. **Methods of surveying and measuring vegetation**. Hurley, Berkshire, England: Commonwealth Bureau of Pastures and Field Crops. 223 p.

This older publication contains valuable information on vegetation sampling methods of cover, density, and frequency. It is especially useful in understanding some of the methods used in the older journal literature, where methods are often not described in full.

vegetation sampling overview, density, cover, frequency, point intercept, line intercept, releve, field techniques.

156. Brown, H. E.; Worley, D. P. 1965. **The canopy camera in forestry**. Journal of Forestry. 63: 674-680.

field techniques, photoplots, photopoints, tools, cover, forest, tree.

157. Brown, J. K. 1976. **Estimating shrub biomass from basal stem diameters**. Canadian Journal of Forest Research. 6: 153-158.

Twenty-five shrub species common to northern Idaho and western Montana were measured for stem basal diameter, average diameter (diameter measures taken every 10cm along the stem and all branches), and stem length. Stem length provided correlation coefficients of 0.70-0.97 with biomass measures for all but two species. Stem basal diameter correlation coefficients were above 0.88 for all but two species. Use of diameter classes (<.5cm,.5 to 2.0cm, and 2 to 5cm) provided nearly as good of correlation as actual measurements, and were much quicker to measure in the field.

field techniques, biomass, production, shrub, shrubland.

158. Brown, J. K. 1974. **Handbook for inventoring downed woody material**. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.

field techniques, prescribed fire, inventory.

159. Brown, L. L. 1960. **A plot marker that tells a story**. Journal of Range Management. 13: 40.

The author describes a plot marker that can be used to inscribe interpretive information for visitors, increasing the value of the plot and perhaps reducing vandalism. Heavy duty aluminum foil wrapped around and stapled to a wooden board proved to be inexpensive but durable. Information can be impressed into the foil with a pen or pencil.

field techniques, permanent plots, monumentation.

160. Brubaker, L. B. 1986. **Tree population responses to climate change**. Vegetatio. 67: 119-130.

succession, forest, ecological models, predicting change, global change monitoring, general examples, tree.

161. Brubaker, L. B. 1988. **Vegetation history and anticipating future vegetation change**. In Agee J.; Johnson D., eds. Ecosystem management for parks and wilderness. Seattle, WA: University of Washington Press: 41-61.

Concern about rising CO_2 levels and possible global warming have prompted the design of several regional monitoring programs to determine the effects on vegetation patterns. Paleo-ecological records evaluated in the last 20 years have demonstrated the temporal variability of vegetation over time and may provide perspective on the types of change to expect and to address in monitoring designs. Vegetation of the Holocene (the last 10,000 years) is much different than that of the full glacial period. Species that dominate the modern landscape occurred then in much smaller populations, and in different species combinations. Thus, modern communities should not be considered highly coevolved complexes. Within a more limited time frame of 3000 to 5000 years, pollen records show most species reached their current range limits during the last half of the Holocene. These assemblages were likely novel; the old growth forest types of the Pacific Northwest, for example, date from this time period. There is no evidence that this assemblage existed in the region or elsewhere before then. Because the genetic change in long-lived tree species over the time span of the Holocene is minimal, the genetic makeup of these species reflect a wider range of selective environments than are occupied today, and observations of current ecology may be inadequate to predict response to future change. In the short-term (last 1000 years), vegetation existing today can often be traced to the Medieval Optimum (warm conditions between 1000 and 1300 AD) and the Little Ice Age (13th century). These variations caused changes

primarily in establishment and disturbance patterns; the resulting vegetation may not respond similarly to disturbances today.

objectives, disturbance, ecosystem, landscape change, pattern, long-term ecological monitoring, global change monitoring, predicting change, large-scale monitoring, community change, community structure, community-level, landscape-level, natural variability.

162. Brummer, J. E.; Nichols, J. T.; Engel, R. K.; Eskridge, K. M. 1994. **Efficiency of different quadrat sizes and shapes for sampling standing crop**. Journal of Range Management. 47: 84-89.

Authors sampled three blocks of 1.2x12m in 160 smaller units of 30x30cm. This allowed numerous plot shapes and sizes to be constructed from the smaller units. Efficiency was evaluated in terms of the number of sampling units necessary to estimate the mean to within 10% (with a 95% confidence level) and the time needed to move between units and clip them. Clipped herbage was separated into 5 groups: the 4 main grass species and other. Variance estimates for total and individual species standing crop decreased with increasing quadrat size, with 68% of the decrease explained by the change in size alone. For 2 species and total herbage, size accounted for 94% of the decrease in variance, and square quadrats were more efficient than same-sized rectangles in the only significant comparisons. This contradicts the common observation that rectangular quadrats intersect more vegetation patches than square quadrats, thus reducing the between-quadrat variation, but square quadrats have been shown in other studies to be more efficient when the size is about the same as the vegetation patches. For the other 2 species, quadrat shape accounted for 23-82% of the variance reduction. In general, the larger quadrats were the most efficient when clipping and travel time were considered. For none of the species was any quadrat less than $0.36m^2$ efficient, and for one species quadrats of $3.6m^2$ were best. For all species, quadrats of $3.6m^2$ were not significantly different from the "best," and so would be most adequate for sampling all species in this study.

field techniques, design, analysis, grassland, rangeland, biomass, production, plot dimensions, precision, sampling design.

163. Brun, J. M.; Box, W. T. 1963. **Comparison of line intercepts and random point frames for sampling desert shrub vegetation.** Journal of Range Management. 16: 21-25.

Sagebrush/grass and sagebrush/shadscalecommunities were sampled using fifteen 50m long line intercepts and fifteen point intercept frames, each 5ft long with 10 pins. The number of sampling units required to estimate mean cover and composition within 10% with a 95% confidence interval was calculated. To reach the desired precision level for composition, the point intercept method required fewer man-hours than the line intercept (20 hours compared to over 29 hrs in the sagebrush/grass and 25 hrs compared to over 46 hrs in the sagebrush/shadscale). The two methods gave similar results for composition, but for percent cover the point frame gave significantly higher estimates. Time required to sample for the desired precision was only 4.15 hrs and 22.4 hrs for the pin frame in the sagebrush/grass and sagebrush/shadscale communities respectively, compared to 23.5 hrs and 92.3 hrs for the line intercept transect.

design, cover, field techniques, precision, sampling design, canopy cover, line intercept, point frames, point intercept, shrub grassland, desert, technique comparison, community-level, community composition.

164. Bruns, D. A.; Wiersma, G. B.; Jr. Rykiel, E. J. 1991. **Ecosystem monitoring at global baseline sites**. Environmental Monitoring and Assessment. 17(1): 3-31.

This paper reports on integrated ecosystem and pollutant monitoring at three global baseline study sites (Alaska, Wyoming, Chile). The authors employ a systems approach to monitoring pollutants which includes: 1) evaluation of source-sink relationships; 2) multifactor monitoring (air, water, soil, biota) of contaminant pathways; and 3) use of ecosystem indicators to detect human influences. The most detailed work is being conducted at the Wind River site in Wyoming, and includes monitoring of terrestrial vegetation attributes including forest community structure, needle retention, litter fall and decomposition, and productivity. The authors suggest that remote protected study sites such as the ones described here are important for documenting potential global change on a world-wide basis.

landscape-level, special sites, global change monitoring, large-scale monitoring, baseline monitoring, integrated monitoring, protected areas, reference areas, monitoring examples.

165. Buckley, R. 1991. **Auditing the precision and accuracy of environmental impact predictions in Australia**. Environmental Monitoring and Assessment. 18: 1-24.

statistical interpretation, monitoring and management, analysis, design, precision.

166. Buckman, R. E.; Van Sickle, C. 1983. **Resource change information is the key to Forest Service planning.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 24-27.

Forest Service inventory and monitoring activities find authority in two key pieces of legislation: the Renewable Resources Planning Act of 1974 (RPA) and the National Forest Management Act (NFMA). Both direct the Forest Service to measure the effects of management actions in order to adapt management and make predictions of future resource availability.

monitoring overviews, agency guidance and policy, adaptive management, monitoring and management, detecting change, predicting change, objectives.

167. Buckner, D. 1985. **Point-intercept sampling in revegetation studies: maximizing objectivity and repeatability**. Proceedings of the American Society of Surface Mining and Reclamation 1985 annual meeting. Denver, CO: American Society of Surface Mining and Reclamation: 110-113.

An overview of the three major methods of determining cover (plots, line intercept, and point intercept) is provided. The author points out that ocular estimation in plots requires significant decisions on the part of the observer because spaces between leaves and stems must be evaluated for individuals, and then the total cover of the individuals within the plot estimated. For both plots and line intercept, decisions are required of the observer to interpret what should be measured as a solid polygon and what should be recognized as a gap in the canopy. There is also the difficulty of projecting the plot or line upward in space to measure plants that are taller than the average observer height. Point-intercept requires the fewest decisions because the measurement is a contact with very small point, the smaller the better. The observer has only to decide what species is being intercepted by the point.

field techniques, technique comparison, community-level, community composition, cover, canopy cover, line intercept, ocular estimation, point frames, point intercept, cover classes.

168. Budd, J. T. C. 1991. **Remote sensing techniques for monitoring land cover**. In: Goldsmith, F. B., ed. Monitoring for conservation and ecology. London: Chapman and Hall: 33-60.

remote sensing, landscape change, landscape-level, community change, community-level, aerial photography, vegetation mapping.

169. Buell, M. F.; Cantlon, J. E. 1950. **A study of two communities of New Jersey Pine Barrens and a comparison of methods**. Ecology. 31: 567-586.

Estimates of relative density (the percent of the total number of individuals contributed by each species) and frequency were compared for 10x10m quadrats and 100m line intercept transects. For the line intercept, the number of individuals of each species that contributed cover on the transect was used to calculate relative density, essentially creating a variable plot with a width varying by canopy size. To measure canopy of trees, a handmade sighting device was developed from simple materials. Construction plans are given. The number of individuals rooted in the quadrat was only 65% to 80% of the individuals counted with canopies intersecting the transect line, and frequency was also less. Because the actual plot size of the transect is unknown, however, this difference is difficult to interpret.

technique comparison, tools, line intercept, density, variable plots, cover, density, field techniques.

170. Buffington, J. D. 1980. **A review of environmental data and monitoring**. In Worf D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D. C. Health and Company: 5-7.

The Interagency Task Force on Environmental Data and Monitoring (organized by the U.S. Department of Environmental Quality) defined environmental monitoring as "the systematic and repetitive collection and analysis of data which can be used 1) to help determine the quality of the environment or condition of natural resources as they are or will be and 2) to help relate environmental quality or natural resources to factors which cause them to change, or to effects produced by such changes." Monitoring is required to identify emerging environmental problems and to evaluate the effectiveness of environmental policies or actions. Current ecological monitoring lacks regional and national focus, similar to the lack of organization shown in air and water quality monitoring in the early 1960's before a national network of data stations was established.

monitoring definitions, monitoring and management, resource management, monitoring overviews, environmental monitoring programs, large-scale monitoring.

171. Buffington, J. D.; Little, L. W. 1980. **Research needs and priorities**. In Worf D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D.C. Health and Company: 194-202.

Participants in this workshop on biomonitoring came to the following conclusions: 1) experimental design is critical to avoid collection of massive quantities of data of minimal use; 2) data interpretation is crucial and especially problematic in agencies where monitoring information filters upwards through several layers before reaching the decision-maker; 3) major environmental impact statements for large facilities should be evaluated after construction to see if the predictions were correct and whether the data were relevant; 4) additional research and characterization of natural variability is needed to separate natural and anthropogenic effects; 5) biomonitoring must be interdisciplinary.

monitoring overviews, environmental monitoring programs, ecological monitoring programs, experimental design, objectives, predicting change, interdisciplinary design, biological significance, natural variability.

172. Bullock, J. A. 1971. **The investigation of samples containing many species. II. Sample comparison**. Biological Journal of the Linnean Society of London. 3: 23-56.

Several similarity indices (Sorensens's, Mountford's, Preston's, the Spearman rank correlation, and Kendall's coefficient) were described and tested on two data sets. The matrix of similarities was subjected to nearest-neighbor clustering and ordination by principle component analysis. Kendall's rank correlation coefficient provided the most interpretable classification and ordination.

analysis, community-level, similarity measures, community composition, community change, multivariate analysis, ordination, clustering.

173. Bullock, J. M.; Hill, B. C.; Dale, M. P.; Silvertown, J. 1994. **An experimental study of the effects of sheep grazing on vegetation change in a species-poor grassland and the role of seedling recruitment into gaps**. Journal of Applied Ecology. 31: 493-507.

An experiment was designed to evaluate vegetation change in response to different grazing regimes. The factorial design had 3 grazing periods and 2 levels of grazing. Initial vegetation was the same in each of the 50x50m paddocks. After 4 years, the vegetation was sampled for cover with sixty-four 10-pin point frames in each paddock. Point sampling was done in both winter and summer. Point data were highly skewed, with 4 graminoid species accounting for over 80% of the intercepts. The point intercept method was thus insensitive to any differences in cover of herbaceous forb species that may have existed between the treatments. These species, however, responded dramatically to the different treatments in permanent $1m^2$ plots (two per paddock) monitored each year since the construction of the paddocks. To sample rare species, which were poorly sampled by the point intercept method, frequency was measured in one hundred $1m^2$ plots within each paddock. Colonization of small artificial gaps (10cm diameter circles) by seedlings was also monitored with twenty gaps per paddock. Half of the gaps were excavated to a depth of 15cm and the soil replaced with sterile loam to monitor colonists from the seed rain. Surface vegetation and root crowns were removed from the other half to monitor colonization from the seedbank as well as the seed rain. Plots were monitored for colonists for over a year.

community-level, herbaceous species, shrub, design, field techniques, community composition, community change, rangeland, seedbank, experimental design, point intercept, frequency, cover, grassland, permanent plots, seedling.

174. Burgess, R. L. 1988. **Community organization: effects of landscape fragmentation**. Canadian Journal of Botany. 66: 2687-2690.

community-level, landscape-level, special sites, disturbance, fragmentation, community change, landscape change, natural areas, species diversity, ecosystem management.

175. Burgess, R. L. 1980. **The national biological monitoring inventory**. In Worf D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D. C. Health and Company: 153-165.

Initiated in 1975 by the Oak Ridge National Laboratory under sponsorship of several U.S. agencies, the National Biological Monitoring inventory consists of voluminous manual files and four computerized databases. Information housed in the database include detailed descriptions of some projects, skeletal descriptions of many additional projects, a directory of principal investigators, and a bibliography of published results. The initial database was generated by sending questionnaires to approximately 7000 investigators in academic and governmental institutions and private organizations.

ecological monitoring programs, general examples, monitoring examples.

176. Burke, I. C.; Lauenroth, W. K. 1993. **What do LTER results mean? Extrapolating from site to region and decade to century**. Ecological Modelling. 67: 19-35.

The authors examined the appropriateness of extrapolating site-level results from the Central Plains Experimental Range (CPER) Long-Term Ecological Research site to the shortgrass steppe region. The basic approach taken by the authors was to conduct a representation analysis based on controlling environmental variables including precipitation, temperature, soil texture, and land use. A GIS database was developed for these variables for the central Great Plains and Central Lowlands region and the CPER. Analysis of geographical representation of these key environmental variables indicated that the CPER could be considered to represent 18.6% of the shortgrass steppe within the central Great Plains, or 5.8% of the central Great Plains as a whole.

large-scale monitoring, long-term ecological monitoring, permanent plots, monitoring and management, monitoring examples.

177. Burke, M. J. W.; Grime, J. P. 1996. **An experimental study of plant community invasibility**. Ecology. 77(3): 776-790.

Permanent plots with variable treatments in disturbance and fertilizer application were given a "seed rain" of a large number of non-native, potentially invasive species. The most successfully invaded treatment was fertile and highly disturbed.

disturbance, community-level, community change, exotics, permanent plots.

178. Burkhart, H. E.; Stuck, R. D.; Leuschner, W. A.; Reynolds, M. A. 1978. **Allocating inventory resources for multiple-use planning**. Canadian Journal of Forest Research. 8: 100-110.

inventory, integrated monitoring, design, objectives.

179. Burkman, W. G.; Hertel, G. D. 1992. **Forest health monitoring**. Journal of Forestry. 90(9): 26-27.

The Forest Health Monitoring Program (FHMP) is a cooperative effort among the Forest Service, Environmental Protection Agency (EPA) and State Foresters. Authority for such monitoring is found in PL-100-521 (The Forest Ecosystems and Atmospheric Research Act of 1988) and PL-101-629 (1990) which directs Forest Service, State, and private foresters to evaluate unnatural stresses, monitor, and report annually. The FHMP uses data from permanent plots and insect, pathogen, and fire incidence data. Permanent plots are coordinated with EPA's Environmental Monitoring and Assessment Program (EMAP), each plot representing about 158,000 acres of forested land.

monitoring examples, agency guidance and policy, community change, community composition, coniferous forest, deciduous forest, large-scale monitoring, permanent plots, global change monitoring, disturbance, tree.

180. Burleson, W. H. 1975. **A method of mounting plant specimens in the field**. Journal of Range Management. 28: 240-241.

A method is described for preserving collections of plants in the field for later reference and identification. Specimens are sandwiched between two sheets of adhesive acetate. Specimens preserved in this manner retained much of their original color for several years and rarely molded.

field techniques, specimen curation.

181. Burley, F. W. 1988. **Monitoring biological diversity for setting priorities in conservation**. In: Wilson, E. O., ed. **Biodiversity**. Washington, DC: National Academy Press: 227-230.

biodiversity, monitoring and management, landscape-level, objectives, special sites.

182. Burns, R. M. 1984. **Importance of baseline information to the research natural area program**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., coordinators. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 50-52.

special sites, baseline monitoring, natural areas, monitoring and management.

183. Burton, A. J.; Ramm, C. W.; Preggitzer, K. S.; Reed, D. D. 1991. **Use of multivariate methods in forest research site selection**. Canadian Journal of Forest Research. 21(11): 1573-1580.

The authors illustrate the use of cluster analysis and ordination techniques to select a subset of ecologically similar research sites from a pool of potential sites.

design, plot selection, sampling design, multivariate analysis, community-level, community classification, clustering, ordination.

184. Busing, R. T. 1993. **Three decades of change at Albright Grove, Tennessee**. Castanea. 58: 231-242.

long-term ecological monitoring, deciduous forest, forest, tree, general examples, special sites.

185. Butler, S. A.; McDonald, L. L. 1983. **Unbiased systematic sampling plans for the line intercept method**. Journal of Range Management. 36: 463-468.

The authors show that for rectangular study areas, systematic placement of line intercepts results in an unbiased estimate of cover if the first transect is placed randomly. The authors caution, however, that spatial regularities may be incorporated into the data by a systematic sample. They identify several benefits of systematic sampling compared to random: more uniform distribution of samples over the study area, reduction in field effort and complexity, and an increase in information per unit cost.

design, sampling design, field techniques, cover, canopy cover, line intercept, systematic sampling, random sampling.

186. Buttrick, S. C. 1984. **Biological monitoring: The Nature Conservancy's perspective**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., coordinators. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 59-64.

The Nature Conservancy will initiate a monitoring project on one of its preserves for four reasons: 1) fulfill legal obligations; 2) determine responses to management activities; 3) track actual or potential threats; and 4) measure progress toward protection goals. The focus of monitoring is always the element(s) for which a preserve was designated, rather than general monitoring of the preserve. In this way, monitoring remains focused. The choice of which elements are monitored is made based on the value (rarity) of the element, the demonstrated need (lack of information or clear threats), and the potential for management actions. The type of monitoring is dictated by the value of the element. Effective monitoring can utilize qualitative techniques such as presence or absence of the element, photopoints, and standardized field observation reports. Quantitative monitoring designs are not standardized, but are tailored for each biological and management situation.

special sites, monitoring overviews, monitoring and management, objectives, natural areas, adaptive management.

187. Byrne, J. C.; Stage, A. R. 1988. **A data structure for describing sampling designs to aid in compilation of stand attributes**. Gen. Tech. Rep. INT-247. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 20 p.

sampling design, data management, forest.

188. Byrne, J. C.; Sweet, M. D. 1992. **Managing data from remeasured plots: an evaluation of existing systems**. Res. Pap. INT-451. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 26 p.

Management of data collected from permanent plots is a critical part of long-term ecological measurements. The authors report on a survey and and evaluate 36 existing database systems for analysis and storage of remeasured growth and yield plot data. Based on this information, the authors define 12 desirable features of database management systems for remeasured plot data.

analysis, permanent plots, data management, long-term ecological monitoring, design.

189. Cain, S. A. 1934. **Sample plot technique applied to alpine vegetation in Wyoming.** American Journal of Botany. 30: 240-247.
field techniques, density, alpine.

190. Cain, S. A. 1934. **Studies on virgin hardwood forests. II. A comparison of quadrat sizes in a quantitative phytosociological study of Nash's Woods, Posey County, Indiana**. American Midland Naturalist. 15: 529-566.
forest, deciduous forest, tree, density, plot dimensions, sampling design, design.

191. Cain, S. A.; Castro, G. M. 1959. **Manual of vegetation analysis.** New York, NY: Harper and Bros. 325 p.
This older book, reissued in 1971, contains a wealth of information on vegetation sampling techniques. It is especially useful for understanding the techniques used in older published studies where methods are not completely described because they were in common use at the time.
field techniques, vegetation sampling overview, density, frequency, cover, line intercept, point intercept, releve, technique comparison, charting.

192. Cairns, J. 1990. **Lack of theoretical basis for predicting rate and pathways of recovery**. Environmental Management. 14: 517-526.
The paper describes a recovery index that predicts the potential of a system to recover from disturbance. The index combines ratings for the following factors: 1) existence of nearby sources of colonizers; 2) transportability of colonizers; 3) condition of habitat after disturbance; 4) presence and persistence of residual effects such as toxicants; 5) chemical-physical environmental quality; and 6) availability of management resources. This index is proposed as an initial attempt to quantify recovery potential, in spite of limited understanding of ecosystem response to and recovery from disturbance and stress. The paper also discusses objectives and management decisions that must be made regarding the level and form of restoration (to original condition or to some alternate state). A checklist of questions is provided for four restoration options: 1) restore to original condition; 2) restore specific attributes; 3) manage for an alternative ecosystem condition; or 4) avoid active restoration efforts and allow recovery to occur naturally. These questions are useful in stimulating thought on situations in addition to restoration, such as identifying the desired outcome of management of pristine or semi-pristine systems and developing resource objectives that should be monitored.
landscape-level, restoration, objectives, disturbance, ecological processes, ecosystem management, monitoring and management, ecological models.

193. Cairns, J. 1986. **The myth of the most sensitive species.** BioScience. 36: 670-672.
landscape-level, indicators, monitoring and management.

194. Cairns, J.; McCormick, P. V.; Niederlehner, B. R. 1993. **A proposed framework for developing indicators of ecosystem health**. Hydrobiologia. 263: 1-44.
landscape-level, indicators, ecosystem management, monitoring and management.

195. Cairns, J.; Patil, G. P.; Waters, W. E., eds. 1979. **Environmental biomonitoring, assessment, prediction and management**. Patil, G. P., series ed. Statistical ecology series, vol. 11. Fairland, MD: International Cooperative Publishing House. 469 p.
The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "Biomonitoring, assessment and prediction in forest pest management systems," "Biological monitoring -- concept and scope," and "The sensitivity of ecological diversity indices to the presence of pollutants in aquatic communities."
monitoring overviews, monitoring and management, analysis, design, diversity indices.

196. Cairns, J.; van der Schalie, W. H. 1980. **Biological monitoring part 1 -- early warning systems.** Water Research. 14: 1179-1196.
landscape-level, indicators, aquatic, monitoring overviews.

197. Cale, W. G.; Henebry, G. M.; Yeakley, J. A. 1989. **Inferring process from pattern in natural communities.** BioScience. 39: 600-605.
Development of ecological predictions must arise not from a simplistic analysis of pattern, but from an understanding of the processes that create the pattern. In this paper, the authors illustrate through simulation that the same pattern can result from a number of different processes. Conversely, patterns indistinguishable from random can result from well defined, non-random processes. Detectable patterns may also fail to result from a non-random process due to masking by a second, complicating process. The authors conclude that pattern analysis alone may not provide much ecological insight.
community-level, pattern, predicting change, objectives, ecological models.

198. Callahan, J. T. 1984. **Long-term ecological research.** BioScience. 34: 363-367.
monitoring examples, long-term ecological monitoring, global change monitoring.

199. Callahan, J. T. 1991. **Long-term ecological research in the United States: a federal perspective.** In Risser P. G., ed. Long-term ecological research: an international perspective. New York, NY: John Wiley and Sons: 9-21.
The author is the administrator for the National Science Foundation's, Long-term Ecological Research Program (LTER). He provides a detailed overview of the history of the program, organizational efforts, collaboration among

LTER sites, existing research projects, and needs for the future. The five core research areas for the program are: 1) pattern and control of primary production; 2) spatial and temporal distribution of populations selected to represent trophic structure; 3) pattern and control of organic matter accumulation in surface layers and sediments; 4) pattern of inorganic input and movement through soils, groundwater, and surface waters; and 5) pattern and frequency of disturbance at the research site.

landscape-level, monitoring overviews, long-term ecological monitoring, monitoring examples, ecological processes.

200. Callaway, R. M.; Davis, F. W. 1993. **Vegetation dynamics, fire and the physical environment in coastal central California**. Ecology. 74: 1567-1578.

landscape-level, community-level, prescribed fire, succession, community change, grassland, herbaceous species, shrub.

201. Campbell, R. C. 1989. **Statistics for biologists. 3rd ed.** New York, NY: Cambridge University Press. 446 p.

This popular book, after several reprintings of the 2nd edition, is now in its third edition and third reprinting. It is an inexpensive book, available in paperback. The author makes no assumptions about previous knowledge of statistics, nor about mathematical ability. Symbols and formulas are minimal, with priority given to understanding concepts rather than mechanics. Examples are fairly simple, primarily biological in nature, and include output from GENSTAT, SPSS, and MINITAB computer programs.

analysis, statistics overview.

202. Canfield, R. 1941. **Application of line interception in sampling range vegetation**. Journal of Forestry. 39: 388-394.

This paper is the first complete published description of the line-intercept method. The sampling unit is recognized as the line transect, along which the intercept of various species or groups of plants is measured. Transects can be located either completely randomly throughout the sampling area or by a restricted random approach in which the area is divided into a number of units equal to the number of sampling units desired, and a transect is randomly located within each of these units. The line transect is proposed as an extremely efficient sampling unit because of the general trend toward greater efficiency as plots become more elongated and less square or round. Two decisions about sampling units (transects) must be made: their length and their number. The most efficient length will depend on the heterogeneity of the vegetation and its cover; recommended lengths are 50ft lines in areas with 5% to 15% cover and 100ft lines in areas of less cover. Most areas will require less than 100 sampling units. Intercept of herbaceous plants should be measured at the ground level, while those of shrubs should be measured on the crown. These conventions provided the most consistent results in tests. The paper also presents a suggested field data sheet.

field techniques, canopy cover, cover, basal area, line intercept, observer variability.

203. Canham, C. D.; Parker, G. G.; Siccama, T. G. 1992. **A directory of long-term studies of vegetation**. Occasional publ. of the Institute of Ecosystem Studies 7. Millbrook, NY: New York Botanical Garden.

long-term ecological monitoring, monitoring examples.

204. Carande, V.; Jameson, D. A. 1986. **Combination of weight estimates with clipped sample data**. Journal of Range Management. 39: 88-89.

Three general classes of methods of estimating production are clipping (which is time consuming and destructive), weight estimation (an ocular estimation of production by the observer) and a combination of the two by double sampling (sample with an optimum ratio of clipped to estimated plots). The authors suggest that traditional application of double sampling has four drawbacks: 1) identifying the optimum ratio requires a presample to determine variances; 2) using a standard ratio rather than the optimum causes a reduction in efficiency; 3) computations require strict adherence to the ratio; and 4) plots clipped for training purposes cannot be used in the calculations. In some weight estimation procedures, clipped plots are used for training, and for calculation of a correction factor. The authors contend that rather than discarding the clipped plots from the sample, they be included. To do so requires accounting for the different variances of the clipped versus the estimated sample (usually observers estimate with a smaller range of values than the clipped plots exhibit, resulting in a corresponding smaller variance). A method and example is provided that illustrates the calculations involved and the increase in precision gained over traditional double sampling techniques.

field techniques, design, biomass, production, weight estimate, sampling design, double sampling.

205. Carlile, D. W.; Skalski, J. R.; Barker, J. E.; Thomas, J. M.; Cullinan, V. I. 1989. **Determination of ecological scale**. Landscape Ecology. 2: 203-213.

landscape-level, scale, pattern, ecosystem, ecological processes.

206. Carpenter, S. R. 1989. **Do we know what we are talking about?** Land Degradation and Rehabilitation. 1: 1-3.

landscape-level, analysis, community change, community-level, restoration, power, precision.

207. Carpenter, S. R. 1990. **Large-scale perturbations: opportunities for innovation**. Ecology. 71: 2038-2043.

Large-scale ecosystem-level experiments and monitoring of ecosystem-level anthropogenic impacts often cannot be replicated, either because the experiment is unplanned or because of the lack of appropriate control sites and adequate funding. This paper provides an introduction to statistical

analysis techniques that may be useful in dealing with such situations, but are rarely presented in statistics courses or in standard statistics texts. Nonrandom change can be detected in a time series if they are long enough. Randomization tests (in which the sampling error is calculated by repeated computer sampling of random permutations of the data) have been applied to whole-system studies to determine differences from controls. If a number of controls are available for the single treatment, conventional t-tests may apply. Bayesian statistics can be used to compare several alternative hypothesis, for each of which the likelihood of obtaining the measured data is computed and compared.

general examples, large-scale monitoring, Bayesian statistics, analysis, time series, randomization tests.

208. Carpenter, S. R. 1989. **Replication and treatment strength in whole-lake experiments**. Ecology. 70: 453-463.

Large-scale experiments often cannot be replicated because of limitations of funding or of available sites. This problem applies to unreplicated anthropogenic disturbances as well. Simulation of whole lake change was used to evaluate sensitivity of standard statistical tests to detect change. Changes had to be substantial (about a 10-fold change) and sustained (3 to 5 years), and replicated using 5 control and 5 treatment lakes in order to produce significant t-test results in at least 80% of the simulated trials. Disturbances with long term effects ("press" type) were better detected than "pulse" disturbances. Paired designs were more effective than random. The key conclusion is that because ecosystem experiments often face a shortage of suitable replicate systems and of funding, the resulting low replication increases the likelihood of erroneous non-significant results (Type II error). These represent enormous costs in terms of wasted research dollars and faulty subsequent management actions. A more cost-effective approach may be collections of unreplicated experiments in which significant differences in single disturbed and natural system pairs are documented in different system types across a range of ecological gradients.

design, landscape-level, landscape change, analysis, pseudoreplication, replication, sampling design, experimental design, disturbance, detecting change.

209. Carpenter, S. R.; Cottingham, K. L.; Stow, C. A. 1994. **Fitting models for ecological interactions to time series with observation errors**. Ecology. 75: 1254-1264.

analysis, time series, trend analysis.

210. Carpenter, S. R.; Frost, T. M.; Heisey, D.; Kratz, T. K. 1989. **Randomized intervention analysis and the interpretation of whole-ecosystem experiments**. Ecology. 70: 1142-1152.

Randomized intervention analysis (RIA) is a type of analysis useful in BACI designs in which the error distribution is derived from the data itself through randomization. The authors claim that this analysis approach is unaffected by non-random data distributions and heterogeneous variances, and is robust to autocorrelations (but see Stewart-Oaten and others (1992) for a critique). In this paper RIA is applied to data from 3 manipulated lakes and 9 reference systems collected over 3 years.

landscape-level, general examples, design, analysis, large-scale monitoring, randomization tests, BACI.

211. Case, J. L.; Toops, P. L.; Shabica, S. V. 1982. **Reference marker-photopoint resources management system**. Research/Resources Management Report SER-62. Atlanta, GA: U.S. Department of Interior, National Park Service. 30 p.

A method for establishment of a permanent photopoint monitoring system is described. Markers were made of PVC pipe set into a cement base approximately 15x15cm (form made from a plastic milk jug). These were buried using a post-hole digger, then cut off at 15cm above ground level. The cement base was required to secure the post in sandy ground and discourage vandals from pulling it up. A removeable cap could be placed on the post to hold a tape to the post. The tape was used to measure distance and azimuth from the photopoint to a reference marker and to a few witness trees. Several photographs were taken from each photopoint, with azimuth recorded for each. A standard data form is illustrated.

field techniques, monitoring examples, photopoints.

212. Caswell, H.; Weinberg, J. R. 1986. **Sample size and sensitivity in the detection of community impact**. Institute of Electrical and Electronic Engineers Oceans 1986 conference proceedings. Washington, DC: Marine Technology Society / Institute of Electrical and Electronic Engineers: 1040-1045.

analysis, community-level, design, power, detecting change, community change, community composition, analysis, sampling design, sample size.

213. Catchpole, W. R.; Wheeler, C. J. 1992. **Estimating plant biomass: a review of techniques**. Australian Journal of Ecology. 17: 121-131.

The following techniques are described and compared: destructive sampling (clipping and weighing), electric capacitance meters ("expensive, fallible, and awkward to use"), line and planar intersect methods, weight estimation (accuracy with trained observers can be within 10% of true weight), relative weight estimation (an improvement over weight estimates for estimating grazing potential), comparative yield method (slow and inconsistent, but improved with a folio of photographs of known biomass), reference unit method for use on shrubs, photo keys, double sampling, point contacts, the disc method (a disc on a pole is dropped down a calibrated post until it rests, the distance dropped a function of vegetation density and height), regressor variables (height, intercepts, dry-weight-rank), and allometric relationships for individual whole tree and shrub biomass estimation. Two tables provide comparison of the methods for different vegetation types.

technique comparison, field techniques, biomass, production, weight estimate, double sampling, dry-weight-rank.

214. Catena, A. J. 1963. **The wandering quarter method of estimating population density**. Ecology. 44: 349-360.

This distance method is designed specifically for species with contagious spatial patterns. Transect directions are established in homogeneous stands. The distance is measured between starting point and the nearest plant that is within a 90° angle centered on the transect direction. Additional distances are measured from that plant to the next, from the next plant to its nearest neighbor (within the 90° angle), and so on. Density is estimated by calculating the distance between individuals within a clump, and between clumps. The method gave fairly good results in tests with artificial and natural populations. The major problems are inadequate sampling of between-clump distances and inadequate coverage of the area.

density, field techniques, plotless methods, wandering quarter.

215. Cattlino, P. J.; Noble, I. R.; Slatyer, R. O.; Kessell, S. R. 1979. **Predicting the multiple pathways of plant succession**. Environmental Management. 3: 41-50.

community-level, objectives, ecological models, predicting change, succession.

216. Causton, D. R. 1988. **Introduction to multivariate methods**. Boston, MA: Unwin Hyman. 342 p.

This book serves as an introduction to plant community classification, gradient analysis, and ordination. It is unique among community plant ecology books because it is written for the uninitiated reader, assuming no prior knowledge, and because it combines in one volume an introduction to field techniques and analysis. Two data sets are used throughout the book to illustrate the techniques, allowing readers to compare options. Mathematics and formulas are kept to a minimum.

community composition, community structure, multivariate analysis, ordination, gradient analysis, field techniques, analysis, community-level, vegetation sampling overview.

217. Cave, G. H.; Patten, D. T. 1984. **Short-term vegetation responses to fire in the upper Sonoran desert**. Journal of Range Management. 37: 491-496.

community-level, landscape-level, field techniques, desert, disturbance, density, biomass, prescribed fire, general examples.

218. Chambers, J. C. 1983. **Measuring species diversity of revegetated surface mines: an evaluation of techniques**. Res. Pap. INT-322. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Three general approaches to measuring diversity (diversity indices, rank correlation tests, and similarity indices) were evaluated for application to measuring the success of surface mine reclamation compared to the pre-disturbance community. Four diversity indices (Simpson, Macintosh, Shannon-Weinner, and Brillouin) were evaluated and rejected because: 1) they assume that all individuals (trees, shrubs, herbs) are equal ecologically; 2) the statistical comparability of these indices has not been demonstrated; 3) changes in values at one end of the scale are not proportionate to those at the other end; 4) diversity indices are insensitive to changes in the apportionment of individuals among species. Rank correlation tests such as the Spearman's rank correlation coefficient have potential, but are limited by their use of relative ranking rather than actual importance values. Similarity values (Ochiai, Dice, Jaccard, Motyka, Bray and Curtis, Sorensen, Euclidean distance, and Schoener's index) are most accurate at intermediate levels of overlap or similarity. These appear to show the most promise, and the best are Motyka, Bray and Curtis, and Spatz's version of the Jaccard index. Sample calculations are given in several appendices.

similarity measures, diversity indices, community composition, community structure, community change, community-level, analysis, multivariate analysis.

219. Chambers, J. C. 1993. **Seed and vegetation dynamics in an alpine herb field: effects of disturbance type**. Canadian Journal of Botany. 71: 471-485.

An area disturbed by road and borrow pit construction was compared to an adjacent late seral, undisturbed turf. Vegetation was sampled in $5m^2$ circular plots distributed randomly in a 50x50m grid. Vegetation cover was ocularly estimated into 12 cover classes. The study also compared the mean density of seed rain and seed bank for the two sites. Standard error for estimates of mean density is included, many of them up to 50% of the mean value or more. The study illustrates the difficulty of sampling seedbank and seed rain to get precise estimates of the mean.

grassland, meadow, succession, disturbance, seedling, seedbank, ocular estimation, cover classes, alpine, precision, community-level, sampling design, field techniques, cover.

220. Chambers, J. C.; Brown, R. W. 1982. **Guide for vegetation analysis of surface mined land**. Contract No. P6690420. Denver, CO: Office of Surface Mining, Region IV. 144 p.

disturbance, vegetation sampling overview, field techniques, density, frequency, cover, herbaceous species, restoration, community-level.

221. Chambers, J. C.; Brown, R. W. 1983. **Methods for vegetation sampling and analysis on revegetated mined lands**. Gen. Tech. Rep. INT-151. Ogden, UT: U.S. Department of Agriculture, Forest Service, Forest and Range Experiment Station. 57 p.

disturbance, vegetation sampling overview, field techniques, density, frequency, cover, herbaceous species, restoration, community-level.

222. Chambers, J. C.; Brown, R. W. 1988. **Technical notes -- a mapping table for obtaining plant population data**. Journal of Range Management. 41(3): 267-268.

The authors describe the construction and use of an acrylic mapping table designed for basic plant demography studies. The mapping table consists of a sheet of plexiglas acrylic mounted on aluminum bars, with adjustable leg supports and a level. A spotting device with crosshairs was constructed to ensure precise relocation of stakes and plants. The plot, in this case, a 20x50 cm grid, was etched into the bottom of the plexiglas. Use of the mapping table is described in detail.

field techniques, tools, demographic techniques, permanent plots, charting.

223. Chambers, J. W.; Cleveland, W. S.; Kleiner, B.; Tukey, P. A. 1983. **Graphic methods for data analysis**. Boston: Duxbury. 395 p.

analysis, graphical analysis, statistics overview.

224. Chatfield, C. 1984. **The analysis of time series. An introduction**. New York, NY: Chapman and Hall. 283 p.

Although this book is titled an introduction, a previous understanding of time series analysis would be helpful. This book is also not for those who are mathematically timid. Examples are included, but are not abundant, and there are no examples that could be directly related to typical ecological monitoring situations. The highly motivated and unintimidated novice could, however, use this book to gain a working knowledge of the most common time series analysis approaches. Exercises are included at the end of each chapter, and answers are given in the back of the book.

time series, analysis, statistics overview.

225. Chavez, P. S.; MacKinnon, D. J. 1994. **Automatic detection of vegetation changes in the southwestern United States using remotely sensed images**. Photogrammetric Engineering and Remote Sensing. 60(5): 571-583.

landscape change, landscape-level, community change, community-level, detecting change, remote sensing, desert.

226. Chew, V. 1976. **Comparing treatment means: a compendium**. Hortscience. 11: 348-357.

analysis, multiple comparisons.

227. Christensen, N. L. 1988. **Succession and natural disturbance: paradigms, problems, and preservation of natural ecosystems**. In Agee J.; Johnson D., eds. Ecosystem management for parks and wilderness. Seattle, WA: University of Washington Press: 41-61.

Four key management questions concerning natural systems can be identified: 1) What should be preserved? 2) How much should be preserved? 3) In what stage should preserves be maintained? and 4) By what means should natural preserves be maintained? Classical successional theory provided fairly easy answers to these questions: 1) communities are the units of preservation (since according to classical successional theory they are consistently discernable units); 2) enough should be protected to maintain dominant plants (since these are the organizers of the community); 3) the stage is irrelevant (since all things will eventually progress to climax): and 4) to maintain the preserves, they should be protected from large scale disturbances such as fire. Past resource management has reflected this classical succession paradigm. Recently, however, both the paradigm and the management approach has been questioned. It now thought that borders between communities are arbitrary, but also that the assemblages that can be separated by ordination and classification techniques do represent real environmental differences or disturbance histories. The amount that should be preserved depends on the scale of the disturbance processes important in that system. Determining the state or condition that should be maintained is especially problematic. The current condition of many forests caused by fire suppression is not "unnatural" in and of itself, although the condition is likely more widespread than presettlement distributions. Returning to the natural fire frequency, however, is often not feasible, and may not even be desirable since fires will not behave "naturally" on landscapes where large areas have been allowed to accumulate fuels. Judicious use of prescribed fire to develop landscape heterogeneity and to balance extreme shifts caused by human interference should be the first priority.

special sites, natural areas, community-level, landscape-level, prescribed fire, ordination, multivariate analysis, objectives, community change, community composition, disturbance, pattern, monitoring and management, vegetation treatments, succession, natural variability.

228. Civco, D. L.; Kennard, W. C.; Lefor, M. W. 1986. **Changes in Connecticut salt-marsh vegetation as revealed by historical aerial photographs and computer assisted cartographics**. Environmental Management. 10: 229-239.

remote sensing, wetland, aerial photography, detecting change.

229. Clapman, A. R. 1932. **The form of the observational unit in quantitative ecology**. Journal of Ecology. 20: 192-197.

plot dimensions, design, sampling design.

230. Clark, K. R. 1990. **Non-parametric multivariate analysis of changes in community structure**. Australian Journal of Ecology. 18: 117-143.

Most multivariate methods used by ecologists are descriptive, pattern-searching approaches. This is inadequate for regulatory monitoring situations in which the question is not whether samples/communities are different, but whether the difference is significant. Multivariate statistical techniques such as MANOVA and canonical correlation are also inappropriate because most community data do not have a multivariate normal distribution, as these tests assume. The author proposes an approach for nonparametric multivariate

analysis of community data, based on ranks in the among-sample similarity matrix. The framework consists of 1) displaying the community pattern using non-metric multi-dimensional scaling; 2) determining the species most responsible for sample groupings through cluster analysis; 3) testing for spatial and temporal differences using permutations of the rank similarity matrix, comparing similarities within sites to those between; and 4) linking community patterns to environmental variables by selecting a subset of the environmental variables that maximizes the rank correlation between the biotic and environmental similarity matrices. These steps are illustrated and clarified in this paper with real examples and data.

community-level, monitoring and management, statistical interpretation, analysis, community composition, community change, multivariate analysis, MANOVA, clustering, nonparametric statistics.

231. Clark, K. R.; Green, R. H. 1988. **Statistical design and analysis for a "biological effects" study**. Marine Ecology Progress Series. 46: 213-226.

design, analysis, statistical interpretation, sampling design, power, detecting change, precision, Type I and Type II errors.

232. Clark, R., ed. 1986. **The handbook of ecological monitoring**. Oxford: Clarendon Press. 298 p.

general book on monitoring, monitoring overviews, ecological monitoring programs, general examples.

233. Clarke, G. M. 1994. **Statistics and experimental design, an introduction for biologists and biochemists**. New York, NY: Wiley. 166 p.

The focus is on concepts behind standard statistics tests and interpretation of results. Worked examples and exercises are included.

analysis, statistics overview.

234. Clymo, R. S. 1980. **Preliminary survey of the peat-bog Knowe Moss using various numerical methods**. Vegetatio. 42: 129-148.

Vegetation of a peat bog was sampled using 18 different people as observers. Because in inital tests, estimation of cover varied up to 10-fold between observers, especially for fine-leaved and widely dispersed species, only species presence or absence was recorded. Vegetation was sampled at intersecting grid points in 12 contiguous 25x25cm quadrats. Quadrats were measured by teams of 5 people (4 observers and 1 recorder) to aid in identification of species by consensus. In addition, 3 taxonomic experts were available to assist all teams. Even with these methods, species misidentification was problematic for some species. The data were analyzed by four types of ordination procedures: non-parametric multidimensional scaling (NP-MDS), principal coordinate analysis (PCO), reciprocal averaging (RA), and principal components analysis (PCA). Their performance was rated in the order given, with PCA providing results that could not be interpreted in terms of any of the known gradients.

field techniques, herbaceous species, pilot study, community composition, wetland, cover, cover classes, ocular estimation, frequency, observer variability, multivariate analysis, analysis, ordination.

235. Cochran, W. G. 1983. **Planning and analysis of observational studies**. New York, NY: John Wiley and Sons. 145 p.

design, sampling design, experimental design, analysis, statistics overview.

236. Cochran, W. G. 1977. **Sampling techniques**. New York, NY: John Wiley and Sons. 428 p.

This book is the standard reference on sampling design. Sampling for proportions, stratified random sampling, cluster sampling, subsampling, and double sampling are all covered at length. Optimization of sampling effort is an important theme. The book was primarily designed for social sample surveys, which are point estimates of social characteristics such as agricultural production, unemployment, and family income. The examples are mostly of these types. It is fairly easy, however, to convert examples into biological situations that require estimates.

design, analysis, experimental design, sampling design, statistics overview.

237. Coetsee, G.; LeRoux, D. P. 1971. **Polygonal plot method for estimating the canopy-spread cover of shrubs**. Proceedings of The Grassland Society of Southern Africa. 6: 176-180.

field techniques, cover, ocular estimation.

238. Coffin, D. P.; Lauenroth, W. K. 1989. **Disturbance and gap dynamics in a semiarid grassland: a landscape-level approach**. Landscape Ecology. 3: 19-27.

herbaceous species, landscape-level, grassland, general examples, pattern, disturbance.

239. Coffin, D. P.; Lauenroth, W. K. 1988. **The effects of disturbance size and frequency on a shortgrass plant community**. Ecology. 69: 1609-1617.

community-level, herbaceous species, grassland, disturbance, community composition, general examples.

240. Coffin, D. P.; Lauenroth, W. K.; Burke, I. C. 1996. **Recovery of vegetation in a semiarid grassland 53 years after disturbance**. Ecological Applications. 6(2): 538-555.

grassland, rangeland, disturbance, community-level, community change, succession, general examples.

241. Cohen, J. 1977. **Statistical power analysis for the behavioral sciences**. New York, NY: Academic Press. 474 p.

This book is the standard reference on power analysis. Although written for social scientists, the examples and

techniques can be fairly easily extended into biological situations. There is no similar volume in biometry or ecology. Readers are assumed to have taken one or two semesters of standard statistics coursework, and to understand standard significance tests. To overcome the common malady of statistics phobia, the author sought to reduce computations and supply a "verbal-intuitive exposition, rich in redundancy and with many concrete illustrations."
analysis, precision, power, statistics overview.

242. Cole, D. N. 1994. **The wilderness threats matrix: a framework for assessing impacts**. Res. Pap. INT-475. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p.
special sites, monitoring and management, landscape-level, wilderness, objectives.

243. Cole, J. W. L.; Grizzle, J. E. 1966. **Applications of multivariate analysis of variance to repeated measurements experiments**. Biometrics. 22: 810-828.
analysis, repeated measures analysis, MANOVA.

244. Collins, B. 1992. **Using 35mm color prints to detect forest change**. Proceedings of the thirteenth biennial workshop on color aerial photography and videography in the plant sciences; Orlando, FL. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 7-13.
This paper illustrates the use of 35-mm color aerial photography in the Forest Inventory and Analysis 1990 update of the Minnesota Forest Inventory (2500 plots). Previous updates had been conducted with black and white photography. The author reports that recent color aerial photos improved disturbance classification accuracy. Using aerial photo analysis, only 116 of the 2500 plots were tagged for field visits based on the occurrence of disturbances since the last inventory. A total of 1150 plots (less than half of the 2500 total) were field checked and included all of the plots with observed disturbance, specific tree checks, and plots needed to verify the STEMS growth model. Use of the color aerial photography resulted in a much more cost-efficient survey.
remote sensing, landscape-level, cover, monitoring examples, inventory, aerial photography, forest, canopy cover, disturbance, large-scale monitoring.

245. Collins, S. L. 1995. **The measurement of stability in grasslands**. Trends In Ecology and Evolution. 10: 95-96.
succession, community change, community-level, detecting change, grassland.

246. Committee on Rangeland Classification, Board of Agriculture, National Research Council. 1994. **Rangeland health-- new methods to classify, inventory and monitor rangelands**. Washington, DC: National Academy Press. 180 p.
ecosystem management, landscape-level, community-level, rangeland, community classification, inventory, monitoring overviews.

247. Conant, F.; Rogers, P.; Baumgardner, M.; McKell, C. M.; Dasmann, R.; Reining, P., eds. 1983. **Resource inventory and baseline study methods for developing countries**. American Association Advisory Science Publ. 83-3. Washington, DC: American Association for the Advancement of Science. 539 p.
This book is designed for planners and managers working with economic assistance programs in developing countries. The book provides methods for inventory and baseline assessment of the four major renewable resource bases: soil, water, plants, and wildlife. Methods generally can be implemented with limited resources. Each chapter is referenced, and contains a list of literature cited as well as suggested additional references. The vegetation chapter is described in more detail under another annotation (McKell and others 1983).
vegetation sampling overview, soils, general book on monitoring, landscape planning, regional planning, field techniques, cover, density, frequency, landscape-level, baseline monitoring, inventory.

248. Conkling, B. L.; Byers, G. E. 1992. **Forest health monitoring field methods guide (internal report)**. Las Vegas, NV: U.S. Environmental Protection Agency.
ecosystem management, landscape-level, forest, tree, monitoring examples, integrated monitoring, field techniques.

249. Connor, J. 1990. **Impact assessment, monitoring and site specific restoration plans for disturbed areas in Rocky Mountain National Park, Colorado.** In: Hughes, H. G.; Bonnicksen, T. M., eds. Restoration '89: the new management challenge: Proceedings of the first annual meeting of the Society for Ecological Restoration; 1989 January 16-20; Oakland, CA. Madison, WI: Society for Ecological Restoration: 543-548.
restoration, special sites, national parks, disturbance, monitoring overviews, objectives, monitoring examples.

250. Conover, S. A. M. 1985. **Environmental effects monitoring and environment Canada: a synthesis of the findings of four workshops.** Ottawa, Ontario: Environment Canada.
monitoring overviews, adaptive management, feedback loops, objectives.

251. Conover, W. J. 1980. **Practical nonparametric statistics. 2nd ed.** New York, NY: John Wiley and Sons. 488 p.
This book is intended as a text for a college-level introductory course in nonparametric statistical methods, and as a reference for researchers. No assumptions are made of prior statistical knowledge, and the first two chapters are spent on explaining probability theory and statistical

inference and hypothesis testing. Each test is presented as a complete explanation, so the book serves well as a reference. A table on the back overleaf identifies appropriate tests for combinations of type of sample (paired, two random, multivariate), hypothesis test, and type of measurement (nominal, ordinal, or interval). Examples are liberal, and each chapter contains exercises, with answers provided for odd-numbered problems.

analysis, statistics overview, nonparametric statistics.

252. Conquest, L. L. 1993. **Statistical approaches to environmental monitoring: did we teach the wrong things?** Environmental Monitoring and Assessment. 26: 107-124.

Most standard statistics texts discuss analysis of data that are comprised of independent observations. In monitoring, most observations are correlated to some degree, either because of spatial or temporal proximity. Similarly, the classic P-value in hypothesis testing is the probability of the observation, or anything more extreme, given the null hypothesis. In monitoring, what is really of interest is the probability that the hypothesis is true, given the observed evidence-- the Bayesian probability. None of the techniques addressing these issues are readily available to resource managers in introductory statistics texts or classes, nor in workshops. In this paper, a discussion of the effects of correlated observations (covariance) and some worked examples are presented. Bayesian theory is introduced, and simple graphical applications demonstrated.

analysis, covariance, Bayesian statistics.

253. Conrad, C. E.; O'Regan, W. G. 1973. **Two-stage stratified sampling to estimate herbage yield**. Res. Note PSW-278. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 5 p.

field techniques, production.

254. Conroy, M. J.; Noon, B. R. 1996. **Mapping of species richness for conservation of biological diversity: conceptual and methodological issues**. Ecological Applications. 6(3): 763-773.

landscape-level, biodiversity, species richness, species diversity, vegetation mapping, species lists.

255. Cook, C. W.; Bonham, C. D. 1977. **Techniques for vegetation measurements and analysis for pre- and post-mining inventory**. Range Science Department Range Science Series 28. Fort Collins, CO: Colorado State University. 93 p.

restoration, community composition, community structure, community-level, field techniques, vegetation sampling overview, inventory.

256. Cook, C. W.; Box, T. W. 1961. **A comparison of the loop and point methods of analyzing vegetation**. Journal of Range Management. 14: 22-27.

field techniques, community-level, cover, technique comparison, loop frames, point intercept, canopy cover, community composition.

257. Cook, C. W.; Stubbendieck, J. 1986. **Range research: basic problems and techniques**. Denver, CO: Society of Range Management. 317 p.

vegetation sampling overview, design, rangeland, field techniques, experimental design.

258. Cook, J. W.; Brady, W. W.; Aldon, E. F. 1994. **The effect of grass plant size on basal frequency estimates**. Grass and Forage Science. 49: 414-421.

field techniques, frequency.

259. Cook, T. D.; Campbell, D. T. **Quasi-experimentation: designs and analysis issues for field settings**. Boston, MA: Houghton-Mifflin. 405 p.

The focus of this book is the design and analysis of social research in a field setting, in contrast to laboratory situations where variables are better controlled. In many ways, this type of research is similar to the kinds of situations that field biologists encounter. The quasi-experimental approach has treatments, outcomes and experimental units, but cannot use random assignment of treatment to eliminate all but the treatment effects. Common designs are those in which the state of the same variable is measured in the same units before and after treatment (nonequivalent group designs), measured several to many times before and after treatment (interrupted time-series), or correlated with several levels of treatment. Examples in this book are all from social research settings, but can be extrapolated to ecological monitoring situations. Mathematics is minimal, primarily relegated to footnotes. The authors depend on text and figures to explain their points.

analysis, design, statistics overview.

260. Cooper, C. F. 1963. **An evaluation of variable plot sampling in shrub and herbaceous vegetation**. Ecology. 44: 565-569.

field techniques, cover, shrubland, shrub grassland, canopy cover, variable plots, technique comparison, tools, shrub.

261. Cooper, C. F. 1957. **The variable plot method for estimating shrub density**. Journal of Range Management. 10: 111-115.

Variable plot sampling, first developed for timber volume estimation, can also be used to determine percent cover of shrubs. The method utilizes a crossarm with a standard rod length. When held up to the eye, the instrument can be used to sight on individual shrubs. Shrub canopies that are apparently larger than the diameter of the crossarm are counted. The number of shrubs counted can be related to the percent shrub cover for the area. The author tested this method in four shrub types and found that it gave similar estimates of cover compared to line intercept, but was much faster. In this study, a gage with a perpendicular crossarm of

4 and 15/64 inches, held 30 inches from the eye, provided the best estimates. The number of individuals counted based on this gage size (all crown diameters not completely obscured by the crossarm) divided by a factor of two gives an estimate of percent cover. Directions and dimensions for construction are given. The author makes the following recommendations for using this method: 1) crossarm length should be calibrated for individual observers; length should cover a target 14.18ft in diameter placed at a distance of 100ft; 2) sampling is most efficiently done in pairs, with one observer delimiting the diameter of shrubs and the other determining whether the individual shrub should be counted; 3) cover over 35% becomes impossible to measure because of the difficulty in delineating individual shrubs; and 4) deviations of individuals from a uniformly round cross-section will result in a biased estimate of cover. The author notes that plotless sampling data can also be used to estimate the number of individuals per unit area, if the mean size of individuals is known.

field techniques, cover, shrubland, shrub grassland, canopy cover, variable plots, technique comparison, tools, shrub, line intercept.

262. Cooperrider, A. V.; Boyd, R. J.; Stuart, H. R. 1986. **Inventory and monitoring of wildlife habitat**. Denver, CO: U.S. Department of Interior, Bureau of Land Management, Service Center. 858 p.

landscape-level, community-level, vegetation sampling overview, field techniques, monitoring overviews, inventory, monitoring examples, baseline monitoring, habitat management.

263. Cormack, R. M.; Ord, J. K., eds. 1979. **Spatial and temporal analysis in ecology**. Patil, G. P., series ed. Statistical ecology series, volume 8. Fairland, MD: International Cooperative Publishing House. 363 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "Time series and spatial patterns in ecology," "The density of spatial patterns: robust estimation through distance methods," "The analysis of ecological maps as mosaics," and "A test of different quadrat variance methods for the analysis of spatial pattern."

analysis, statistics overview, pattern, time series, density, field techniques.

264. Cormack, R. M.; Patil, G. P.; Robsen, D. S., eds. 1979. **Sampling biological populations**. Patil, G. P., series ed. Statistical ecology series, volume 5. Fairland, MD: International Cooperative Publishing House. 425 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "Line intersect sampling -- statistical theory, applications and suggestions for extended use in ecological inventory," "Sampling theory on repeated occasions with ecological applications," "Trends in the sampling of forest populations," "Line transect and related issues," "Estimating population densities from variable circular plot surveys," "Sampling of large objects."

field techniques, density, cover, sampling design, design, variable plots, line intercept.

265. Cost, N. D.; Knight, H. A. 1983. **Forest classification considerations for monitoring changes and trends**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 157-161.

Initial inventory methodologies used random plot placement, irrespective of changes in forest stand types, management use, or condition. While this approach was successful at estimating tree volume, it provided little information on stand structure or condition changes. Up to 30% of the plots were found to straddle stand boundaries. With a modification, inventory plots were confined to a single classified stand type, and the data had broader usefulness. Classification strategy included ownership, site index, stand age and tree diameter, past treatment and disturbance, treatment opportunities, and size of condition area.

design, community-level, inventory, random sampling, community structure, community classification, stratified sampling, DBH, disturbance, sampling design.

266. Costello, D. F.; Klipple, G. F. 1939. **Sampling intensity in vegetation surveys made by the square-foot density method**. Agronomy Journal. 31(9): 800-810.

field techniques, cover, density.

267. Cottam, G.; Curtis, J. T. 1956. **The use of distance measures in phytosociological sampling**. Ecology. 37: 451-460.

Four distance methods (closest individual, nearest neighbor, random pairs, and point-center quarter) were tested on three forest communities and a random artificial sample by comparing to density measured in quadrats. The authors concluded that all methods could yield an accurate estimate of density and basal area, but the sample size needed to achieve adequate precision varied with the method. The closest individual was the easiest to implement and understand, but required a large number of sample points. Nearest neighbor required slightly fewer sample points, but the authors note it tended to under-sample trees that were close together (underestimating density). Random pairs and quarter method required least number of sampling points, largely because of the additional distances measured at each point. The authors recommended the quarter method. An interesting observation made in this study was that some observers had a subconscious tendency to place sample points so as to capture large or unusual trees.

field techniques, distance methods, density, nearest neighbor, point-center methods, random pairs, forest, observer variability, technique comparison.

268. Coughenour, M. B.; Singer, F. J.; Reardon, J. 1994. **The Parker transects revisited: long-term herbaceous vegetation trends on Yellowstone's northern winter range.** Plants and their environments: Proceedings of the first biennial scientific conference on the Greater Yellowstone ecosystem; 1991 September 16-17; Mammoth Hot Springs, Yellowstone National Park, WY. Tech. Rep. NPS/NRYELL/NRTR; 93/XX. Denver, CO: U.S. Department of Interior, National Park Service, Natural Resource Publication Office: 73-95.

monitoring examples, permanent plots, field techniques, cover, frequency, point intercept, loop frames, community-level, community change, long-term ecological monitoring, special sites, national parks.

269. Covington, W. W.; Moore, M. M. 1994. **Southwestern ponderosa pine forest structure**. Journal of Forestry. 92: 39-47.

By mapping and dating stumps, the authors created a "virtual forest," that could be viewed and modeled using computer simulation. Modern density of trees was much higher than in presettlement times (851 compared to 19 trees per acre). Historically, ponderosa pine forests were parklike areas with grassy understories and few large trees.

community-level, landscape-level, forest, tree, succession, prescribed fire, long-term ecological monitoring, forest, coniferous forest, community structure, community change.

270. Cowley, E. R. 1992. **Protocols for classifying, monitoring, and evaluating stream/riparian vegetation on Idaho rangeland streams**. Water quality monitoring protocols rep. 8. Boise, ID: Idaho Department of Health and Welfare, Division of Environmental Quality. 37 p.

This report is part of a series published by the Idaho Division of Environmental Quality for standardized monitoring and inventory of streams to determine if state water quality objectives are being met. Monitoring techniques are described in detail, complete with data sheet and data summary descriptions. Techniques included in this manual are: green line, woody species age class measurement, utilization, woody vegetation cover, and photopoints.

field techniques, general examples, cover, agency guidance and policy, riparian, canopy cover, photopoints.

271. Cox, R. F. 1976. **The robust estimation of the density of a forest stand using a new conditioned distance method**. Biometrika. 63: 493-499.

The author develops a distance measure estimator of density (or its inverse, mean area per tree) that is robust to different spatial distributions. The estimator is based on two measures, point to nearest tree (X), and that tree to nearest neighbor (Y). These are split into two groups, one including the pairs where $Y \leq 2X$ and the other where $Y > 2X$. This estimator worked well for distributions ranging from extremely aggregated to regular.

field techniques, distance methods, nearest neighbor, density, tree, plotless methods.

272. Cressie, N. A. C. 1991. **Statistics for spatial data.** New York, NY: John Wiley and Sons. 900 p.

analysis, statistics overview, pattern, pattern, analysis.

273. Cressie, N. A. C.; Whitford, H. J. 1986. **How to use the two sample t test**. Biometrical Journal. 28: 131-148.

analysis, parametric statistics.

274. Crocker, R. L.; Tiver, N. S. 1948. **Survey methods in grassland ecology**. Journal of The British Grassland Society. 3: 1-26.

field techniques, grassland, herbaceous species, cover, point intercept.

275. Crome, F. H. J.; Thomas, M. R.; Moore, L. A. 1996. **A novel Bayesian approach to assessing impacts of rain forest logging**. Ecological Applications. 6(4): 1104-1123.

analysis, Bayesian statistics, , design, BACI, permanent plots, power, precision, replication, statistical interpretation.

276. Crow, G. E.; Ritter, N. P.; McCauley, K. M.; Padgett, D. J. 1994. **Botanical reconnaissance of Mountain Pond Research Natural Area**. Gen. Tech. Rep. NE-187. Dover, DE: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 11 p.

This publication is the first in a series of published botanical reconnaissance surveys for research natural areas, commissioned by the Northeastern Experiment Station of the Forest Service. Baseline floristic conditions were documented through intensive surveys of vascular plants. Surveys were stratified by ecological land type and forest cover type. Vouchers were made of all vascular plants found within the natural area. An annotated checklist was compiled describing species distribution and abundance, and reference to collection number.

special sites, inventory, general examples, species lists, specimen curation, baseline monitoring, natural areas.

277. Crow, T. R. 1980. **A rain forest: a 30 year record of change in structure and composition. Elverde, Puerto Rico**. Biotropica. 12(1): 42-55.

Changes over 30 years in a moist tropical forest in Puerto Rico weremonitored in a permanent reference plot. Within the 60x120m plot, all trees >4cm diameter (DBH) were tagged and their diameter measured 10 times over the 30 years. All heights were measured twice over the period. This design allowed for monitoring number and diversity of species, basal area, number of stems, ingrowth (new trees), and mortality. Biomass was estimated using an allometric relationship.

community-level, biomass, production, field techniques, tree, DBH, heights, monitoring examples, disturbance, community composition, community structure, diversity indices, species richness, species lists, species diversity, succession, forest, long-term ecological monitoring, permanent plots.

278. Crowder, M. J.; Hand, D. J. 1990. **Analysis of repeated measures**. London: Chapman and Hall. 253 p.

Repeated measurements are those in which the same characteristic is measured on the same observational unit on more than one occasion (such as diameter of the same tree or density of a species within a permanent plot). The book is written for the intermediate to advanced student of statistics. The authors assume the reader understands basic to intermediate concepts in univariate and multivariate statistics. Formulas are abundant, but the techniques are well illustrated with examples and the author's writing style, unlike the material, is not difficult. Techniques include univariate analysis of variance, multivariate approaches, regression models, two-stage linear models, crossover designs, and techniques for categorical data.

analysis, repeated measures analysis, statistics overview.

279. Croy, C. D.; Dix, R. L. 1984. **Notes on sample size requirements in morphological plant ecology**. Ecology. 65: 662-666.

Sixteen species of various life forms were measured for standard morphological characteristics: height, diameter at standard height, maximum diameter, horizontal distance (from the emergence of the base to the apex), leaf blade length and width, and the ratio of height to diameter. Twenty-five individuals of each species were randomly selected by locating random points and selecting the nearest individual. For only a few of the species/characteristics combinations was the sample size of 25 adequate to bring the 95% confidence interval to within 10% of the mean. Horizontal distance was the most variable for most species, requiring sample sizes of up to 1025. Height, maximum diameter and, and leaf length and width were less variable. Time required to measure the various attributes ranged from 2 minutes to more than 30, with the more time-consuming measures associated with trees. The authors note sampling areas typically failed to contain enough individuals to measure characteristics to desired precision; sampling areas either need to be enlarged, or desired precision decreased.

field techniques, crown diameter, performance, heights, sampling design, precision, tree.

280. Croze, H. 1984. **Monitoring within and outside protected areas**. In: McNeely, J. A.; Miller, K. R., eds. National parks, conservation and development: the role of protected areas in sustaining society. Washington, DC: Smithsonian Press: 628-633.

This paper discusses the need to develop monitoring programs for protected areas that address the surrounding landscape context. One of the main concerns in managing protected areas is to ensure the security of the area, and to understand and maintain its ecological processes. The author provides a general discussion of considerations of ecological monitoring in protected areas. He then describes in some detail the Global Environmental Monitoring System (GEMS). Much of GEMS activities center on monitoring of pollutants, climates, and renewable natural resources. Natural resources monitored include soils, forests, arid rangelands, and endangered species and habitats. Most of the monitoring described is fairly broad in character.

special sites, landscape-level, general examples, integrated monitoring, ecological monitoring programs, natural areas.

281. Cullen, P. 1991. **Biomonitoring and environmental management**. Environmental Monitoring and Assessment. 14: 107-114.

integrated monitoring, monitoring and management, monitoring overviews.

282. Cullinan, V. I.; Thomas, J. M. 1992. **A comparison of quantitative methods for examining landscape pattern and scale.** Landscape Ecology. 7: 211-227.

Three datasets, two simulated and one real, were tested with several quantitative methods to compare pattern detection. One of the two simulated patterns was random, the second had a defined regular pattern. The real dataset was a 2050m transect of bunchgrass cover. In this paper, six methods (tests of non-randomness, estimation of patch size, spectral analysis, fractals, variance ratio analysis, and correlation analysis) were examined in light of four major research areas in landscape ecology: 1) the development and dynamics of spatial heterogeneity; 2) spatial and temporal interactions and exchanges across heterogenous landscapes; 3) influences of spatial heterogeneity on biotic and abiotic processes; and 4) management of spatial heterogeneity. Each method was evaluated based on how well it estimated or detected patch size and distribution, spatial variation, spatial correlation, scale of pattern, lag, sample size, multiple scales, and ecological change. No one method estimated all factors well.

landscape-level, scale, large-scale monitoring, pattern, landscape change, pattern, patch dynamics, ecosystem management, technique comparison.

283. Cunia, T. 1968. **Management inventory (CFI) and some of its basic statistical problems**. Journal of Forestry. 66: 342-350.

sampling design, design, analysis, inventory.

284. Cunningham, G. M. 1975. **Modified step-pointing: a rapid method of assessing vegetative cover**. Journal of Soil Conservation. 31: 256-265.

field techniques, cover, point intercept.

285. Curtis, J. T.; McIntosh, R. P. 1950. **The interrelations of certain analytic and synthetic phytosociological characters**. Ecology. 31: 434-445.

For the most effective frequency measures, the quadrat size should be one to two times as large as the mean area per individual of the most common species. For randomly distributed species, this would result in a frequency of 63% (for the smaller quadrat) to 83%.

field techniques, frequency, plot dimensions, design.

286. Curtis, R. O. 1983. **Procedures for establishing and maintaining permanent plots for silvicultural and yield research**. Gen. Tech. Rep. PNW-155. Olympia, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 56 p.

A standard method is described for establishing square permanent plots to measure changes in timber volume over time. Trees are tagged, measured for diameter (DBH), and classified for condition. A sample of trees is used to determine canopy height and age of stand. Crown dimensions may be measured, site index calculated, and stem maps made.

community-level, forest, tree, permanent plots, DBH, heights, general examples, community structure, community change, coniferous forest, crown diameter, tree-ring analysis, crown diameter, field techniques, production.

287. Curtis, R. O.; Bruce, D. 1968. **Tree heights without a tape**. Journal of Forestry. 66: 60-61.

This paper describes a geometric approach to measuring tree heights by using a pole of known length and comparing the apparent length of the pole at the base of the tree to the height of the tree. Comparisons of the relative standard error of estimated tree height to real tree height for different sized poles suggests that the length of the pole should not be less than one-fifth the height of the tree, and perferably closer to one-fourth. In a field test, this method performed well in comparison with standard tape methods. On uneven ground, or in areas of high underbrush, time savings using this method were significant.

tools, field techniques, forest, tree, coniferous forest, deciduous forest, heights.

288. Dale, V. H.; Franklin, R. L. A.; Post, W. M.; Gardner, R. H. 1991. **Sampling ecological information: choice of sample size.** Ecological Modelling. 57: 1-10.

Determining the adequacy of sample size is a critical part of any environmental study. Standard sample size formulas are based on the assumption of a normally distributed population. Appropriate sample sizes for non-normal distributions are more difficult to determine. In this paper, computer simulation was used to explore the effects of kurtosis and skewness of the distribution on adequacy of sample size. Four distribution patterns were compared: uniform, normal, triangular, and lognormal, each with a range of levels of kurtosis and skewness. Simulations show that although estimates of the mean improve with sample size, samples from a lognormal distribution consistently underestimate the mean. The standard error-to-mean ratio illustrated a typical pattern for each distribution type. The authors suggest that an approach for determining adequate sample size should be two-phased. First, the standard error-to-mean ratio should be plotted as sampling units are added until it is less than 10%. Values of kurtosis and skewness should then be plotted with Pearson frequency curves. If the value falls within the type I, I(U) or I(J) regions, it is likely that an adequate number of sampling units have been measured. (See Dixon and Garrett 1993, for a critique of this paper.).

design, analysis, precision, sample size, sampling design.

289. Dallmeier, F. 1996. **Biodiversity inventories and monitoring: essential elements for integrating conservation principles with resource development projects**. In: Szaro, R. C.; Johnson, D. W., eds. Biodiversity in managed landscapes. New York, NY: Oxford University Press: 221-236.

The Smithsonian Institution and UNESCO Man and the Biosphere Program (SI/MAB) are working to establish a global network of long-term biodiversity inventory and monitoring plots. The goal is to establish a network of over 300 plots world-wide by the year 2000. SI/MAB works with host countries to implement monitoring in a series of steps: 1) development of conceptual framework, management goals, and objectives; 2) collation and evaluation of existing information; 3) inventory to identify important elements of biodiversity for monitoring; 4) design and implementation of monitoring, using standard protocols where possible; and 5) standard methods of data analysis, interpretation, and reporting, based on formatted standard databases. At most sites, methods involve measuring and mapping woody vegetation. Training is a critical part of the program, ensuring that local expertise will be available for continued measurement and analysis of permanent plots.

community-level, integrated monitoring, monitoring examples, biodiversity, community composition, long-term ecological monitoring, permanent plots, ecological monitoring programs.

290. Dallmeier, F.; Kabel, M.; Rice, R. 1992. **Methods for long-term biodiversity inventory plots in protected tropical forests**. In Dallmeier F., ed. Long-term monitoring of biological diversity in tropical forest areas: methods for establishment and inventory of permanent plots. Man and the Biosphere Digest 11. Paris, France: United Nations Educational, Scientific and Cultural Organization: 11-45.

Plot methodology used in one temperate and four tropical protected areas is described. The method utilizes a cluster of twenty-five square plots (1 hectare), arranged either in a block, a belt transect, or along a meandering path (such as along a river). Each plot is marked at the corners and is subdivided into twenty-five 20x20m quadrats (also marked at corners), which are further divided into 5x5m subquadrats. Plots are surveyed for accuracy. Within each, all trees >10cm diameter (DBH) are tagged, measured for DBH (painting the point of measurement to ensure comparable remeasurements), assessed for condition (in standard classes), and mapped

from two corners of the 20m plot. Although this publication presents a specific methodology, the general observations, problems, remeasurement strategies, and techniques can be applied to other monitoring projects.

general examples, long-term ecological monitoring, demographic techniques, community change, community composition, community structure, DBH, permanent plots, special sites, protected areas, forest.

291. Danford, M. B.; Hughes, H. M.; McNee, R. C. 1960. **On the analysis of repeated-measurements experiments.** Biometrics. 16: 547-565.

analysis, repeated measures analysis.

292. Daniel, W. W. 1990. **Applied nonparametric statistics. 2nd edition**. Boston, MA: PSW-Kent Publishing Company. 635 p.

This book is designed for a student or reader with an understanding of college algebra. Previous statistical experience is not assumed, although it would be helpful. The book is arranged by data type (e.g., data from two independent samples, paired data, three or more independent or related samples, etc.), with each chapter presenting methods for the particular data type. Each test is presented in a format of 1) assumptions; 2) hypotheses; 3) test statistic; and 4) decision rule. Each method is first presented in general terms, then illustrated with an example. This approach is helpful for someone who wishes to use the book as a reference, or someone who can only study a chapter at a time rather than a whole book. Additional references are provided and exercises are abundant. In addition to the excellent organization of the book, its use as a reference is enhanced by a table on the front overleaf describing potential tests for type of problem by data type.

analysis, statistics overview, nonparametric statistics.

293. Danielsen, K.; Halvorson, W. L. 1988. **Valley oak inventory and monitoring at Santa Monica Mountains**. Natural Resource Rep. NPX-NR-89-01. Denver, CO: U.S. Department of Interior, National Park Service.

field techniques, tree, inventory, woodland, monitoring examples.

294. Dasmann, W. P. 1948. **A critical review of range survey methods and their application to deer range management**. California Fish and Game. 34: 189-207.

inventory, production.

295. Daubenmire, R. F. 1959. **Canopy-coverage methods of vegetation analysis**. Northwest Science. 33: 43-64.

This paper introduces the widely used Daubenmire scale of canopy cover estimation. In comparison with line intercept, forty to fifty $0.1m^2$ plots gave estimates of cover nearly identical to 350m of line interception, although the standard error of the plots was quite high.

field techniques, cover, canopy cover, ocular estimation, cover classes, technique comparison, line intercept.

296. Davis, G. E. 1989. **Design of a long-term monitoring program for Channel Islands National Park, California**. Natural Areas Journal. 9(2): 80-89.

This paper describes the objectives and overall framework for a long term ecological monitoring program for Channel Islands National Park. This comprehensive program utilized a population dynamic approach to monitoring of all biota. Index taxa were selected to include representation of a broad array of ecological roles, examples of different trophic levels, and other ecosystem indicators. Ten separate publications were developed to define specific monitoring protocols for each resource category, including terrestrial vegetation. A total of 156 vascular plants were selected for monitoring. Two vegetation monitoring protocols were utilized for monitoring unusual and representative plant communities: 1) periodic vegetation mapping with permanent transects and 2) point-intercept. Specific vegetation measures included species composition, frequency of occurrence, height, and cover.

monitoring examples, long-term ecological monitoring, national parks, ecological monitoring programs, indicators, large-scale monitoring, integrated monitoring, permanent plots, point intercept, frequency, cover, community-level, heights, community composition, community change.

297. Davis, G. E. 1993. **Design elements of monitoring programs: the necessary ingredients for success**. Environmental Monitoring and Assessment. 26: 99-105.

Monitoring is important, claims the author, for several reasons: 1) determine present and future health of ecosystems; 2) describe natural range of variability; 3) diagnose abnormal conditions in time to take evasive action; and 4) identify the potential agents of abnormal change. He likens monitoring to medicine, in which vital signs are monitored; unfortunately, however, we have yet to identify the "vital signs" for ecosystems. In this framework, focused on monitoring in natural areas, the players are identified and the process described. It is three-staged. In the first, a conceptual model of the ecosystem is developed based on literature reviews and field surveys. Critical components in the model are then selected for monitoring and design protocols developed. Monitoring is implemented by obtaining necessary funding, personnel, and management support. Finally, the importance of continued monitoring is illustrated through periodic synthesis and reporting.

objectives, monitoring examples, monitoring definitions, monitoring overviews, baseline monitoring.

298. Davis, G. E.; Halvorson, W. L. 1989. **Natural resources monitoring program development plan, Western Region, National Park Service**. Western Region Working Group on Natural Resources Monitoring. Ventura, CA: U.S. Department of Interior, National Park Service.

special sites, monitoring examples, national parks, agency plans, ecological monitoring programs, monitoring overviews.

299. Davy, A. J.; Jefferies, R. L. 1981. **Approaches to the monitoring of rare plant populations**. In: Synge, H., ed. The biological aspects of rare plant conservation. New York, NY: John Wiley & Sons: 219-232.
monitoring overviews, rare species.

300. Davy, P. J.; Jakeman, A. J. 1984. **The relative efficiency of point count estimators of areal cover**. Acta Stereologica. 3: 3-10.
field techniques, cover, point intercept.

301. Dawkins, H. C. 1983. **Multiple comparisons misused: why so frequently in response curve studies?** Biometrics. 39: 789-790.
multiple comparisons, analysis, repeated measures analysis.

302. Dawson, B. E. 1981. **Relative effectiveness of true-color, color infrared, black and white infrared and red-band sensitive films in identification of plant species**. Arcata, CA: Humboldt State University. 101 p. Thesis.
remote sensing, aerial photography.

303. Day, R. W.; Quinn, G. P. 1989. **Comparisons of treatments after an analysis of variance in ecology**. Ecological Monographs. 59: 433-463.
statistics overview, analysis.

304. De Becker, S.; Mahler, D. 1986. **Photographing quadrats to measure percent vegetation cover**. Natural Areas Journal. 6(1): 67-69.
tools, field techniques, cover, photoplots.

305. Dean, S.; Burkhardt, J. W.; Meeuwig, R. O. 1981. **Estimating twig and foliage biomass of sagebrush, bitterbrush, and rabitbrush in the Great Basin**. Journal of Range Management. 34: 224-227.
field techniques, shrub, shrub grassland, rangeland, biomass, production.

306. Del Moral, R.; Wood, D. M. 1988. **Dynamics of herbaceous vegetation recovery on Mount St. Helens, Washington, USA, after a volcanic eruption**. Vegetatio. 74: 11-27.
general examples, field techniques, community-level, community change, cover, disturbance, succession, herbaceous species.

307. Delcourt, H. R.; Delcourt, P. A. 1988. **Quaternary landscape ecology: relevant scales in space and time**. Landscape Ecology. 2: 23-44.
A system of spatial and temporal scales based on logarithmic (base-10) separation of spatial and temporal levels is proposed as a standard approach to evaluating and communicating ecosystem processes and patterns. The Megascale involves events on a global (greater than 10 to the 14th power (10^{14}) meter^2 in area) to continental (10^{12} to $10^{14}m^2$) scale of rare frequency (>100,000 years), such as continental drift and uplift. The Macroscale (10^{10} to $10^{12}m^2$; 10,000 to 100,000 years) is of regional scale, with disturbances such as climatic fluctuations due to ice ages. The Mesoscale (Mesoregion, 10^8 to $10^{10}m^2$, and Microregion, 10^6 to 10^8m^2) involves regional disturbances such as climatic fluctuations during the Holocene and associated species migrations. The Microscale level is the site level, and is divided into Macrosite (10^4 to 10^6m^2; e.g., large fires), Mesosite (10^2 to 10^4m^2; e.g., severe site-specific storms, annual patterns of precipitation and run-off) and Microsite ($<10^2m^2$; e.g., animal disturbances and daily weather patterns throughout the year).
disturbance, ecological processes, ecosystem, pattern, landscape change, scale, landscape-level.

308. Deming, W. E. 1975. **On probability as a basis for action**. American Statistician. 29: 146-152.
analysis, statistical interpretation, monitoring and management.

309. Dennis, B. 1996. **Discussion: should ecologists become Bayesian?** Ecological Applications. 6(4): 1095-1103.
power, precision, analysis, Bayesian statistics.

310. Department of the Environment and Countryside Commission. 1986. **Monitoring landscape change**. Borehamwood: Huntingdon Technical Services.
This ten-volume series provides information on methods as well as guidance on development of monitoring projects.
general book on monitoring, landscape-level, community-level, field techniques.

311. Despain, D. W.; Ogden, P. R.; Smith, E. L. 1991. **Some methods for monitoring rangelands and other natural area vegetation**. Extn. Rep. 9043. Tucson, AZ: University of Arizona.
field techniques, frequency, density, cover, rangeland, natural areas.

312. deSwart, E.; vander Valk, A. G.; Koehler, K. J.; Berendregt, A. 1994. **Experimental evaluation of realized niche models for predicting responses of plant species to a change in environmental conditions**. Journal of Vegetation Science. 5: 541-552.
The elevational niche of wetland species in 10 experimental wetland cells was measured prior to 2 years of flooding which killed all species. Water levels were then returned to treatment levels of 0cm (control), 30cm, and 60cm above the long-term normal water level before flooding. The hypothesis was that after 5 years, species would inhabit the elevational niches predicted by those measured before flooding. The elevational gradient was considered to be the controlling environmental factor; differences between cells of all other common gradients such as soil, organic matter content, pH, and water chemistry were negligible. The results did not support the hypothesis; in

more than 60% of the comparisons for all species, post flooding frequency by elevation was statistically different from predicted. The best predictive values were in control cells. A number of hypotheses for the discrepancy were postulated. This study illustrates that even in systems with a dominant environmental gradient, predicting species response to change is difficult, and designing monitoring to measure the change is also problematic.

objectives, community-level, ecological models, disturbance, community composition, community structure, succession, wetland, detecting change, predicting change.

313. Dethier, M. N.; Graham, E. S.; Cohen, S.; Tear, L. M. 1993. **Visual versus random-point percent cover estimations: 'objective' is not always better**. Marine Ecology Progress Series. 96: 93-100.

Cover of sessile marine species was measured with visual estimates and point quadrats. Cover was estimated in 50x50cm quadrats. Visual estimates were made with the aid of 25 smaller squares (10x10cm) gridded in the larger frame. Each filled square was considered 4% cover; incompletely filled squares were grouped. Point intercepts were done with a fine mesh screen, stretched over the plot, through which a metal rod was dropped. Location of the 50 points within the quadrat was random. A second test was conducted using computer simulated quadrats. These were sampled by visual methods similar to those above, and by two tests of point intercepts (50 and 100 intercepts). In the field, the point intercept method missed 19% of the 85 species occurring on the plots. Cover of all of these species was less than 2%. Visual estimates were more similar between observers than point intercepts, and were generally lower than the cover values estimated by point intercepts. In the simulation study, the visual estimates consistently gave values closer to the true cover value. Point intercepts could result in widely divergent values, although with repeated sampling the measured mean converged on the true value. Field sampling using point intercepts took approximately twice the time as visual estimates. Sample size calculations suggested that 50 or 100 points, which is often used as a standard, may be inadequate to distinguish even moderate differences (369 points were needed to distinguish 40% cover from 45% with a 95% confidence). In summary, visual estimates produced more accurate and less variable and biased measures of cover compared to point intercept. In addition, a larger sample could be measured with the rapid visual method, providing a more precise measure of cover in patchy communities.

community-level, field techniques, community composition, cover, canopy cover, point frames, point intercept, ocular estimation, observer variability, rare species, tools, technique comparison, precision.

314. Diaz, N.; Apostol, D. 1994. **Incorporating landscape ecology concepts in forest management: forest landscape analysis and design**. In: Covington, W. W.; DeBano, L. F., tech. coords. Sustainable ecological systems: implementing an ecological approach to land management; 1993 July 12-15; Flagstaff, AR. Gen. Tech. Rep. RM-247. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 162-168.

To implement ecosystem management, managers need a tool to analyze landscapes and design target future landscapes. The Forest Landscape Analysis and Design (FLAD) method analyzes five components of the landscape: landscape structures (forest matrix, corridors, and patches within the matrix such as natural openings and logged areas), landscape flows (movement of organisms and elements through the landscape), relationship between flows and structure, natural disturbances and succession, and linkages with areas outside the area under consideration. This analysis is used to develop design objectives for the landscape. These objectives describe the kinds, sizes, shapes, and arrangements of the desired landscape structures.

landscape-level, monitoring examples, objectives, corridors, disturbance, ecosystem management, fragmentation, pattern, landscape change, large-scale monitoring.

315. Diaz, S.; Acosta, A.; Cabido, M. 1992. **Morphological analysis of herbaceous communities under different grazing regimes**. Journal of Vegetation Science. 3: 689-696.

Morphology-based approaches to community analyses may be more effective than floristic approaches for comparisons of communities that are structurally similar but differ in floristic composition, for species that are taxonomically distant but have convergent forms and ecological functions, and for communities which are floristically similar but structurally different. Vegetation under 4 grazing regimes was sampled in four 3x5m plots at 3 topographically similar sites. Floristic data were collected within each plot with eight 20x20cm frequency plots. Morphological traits (annual vs. perennial, spines, pubescence, height, growth form, leaf length and width/length ratio, leaf angle, leaf dissection, leaf texture) were recorded on 10 random individuals from each site for those species present in 10% or more of the sample quadrats. Data were analyzed by multivariate techniques to group morphologically similar species. Although the vegetation was floristically similar under the different grazing treatments, differences in morphology and structure were apparent, with more annuals and prostrate plants in heavily grazed sites, compared to more taller, vertical-leaved plants in ungrazed sites.

community-level, multivariate analysis, community composition, community structure, community change, community comparisons, field techniques, frequency, grassland, herbaceous species.

316. Dickerman, J. A.; Stewart, A. J.; Wetzel, R. G. 1986. **Estimates of net annual aboveground production: sensitivity to sampling frequency**. Ecology. 67: 650-659.

production, biomass, field techniques.

317. Dickinson, K. J. M.; Mark, A. F.; Lee, W. G. 1992. **Long-term monitoring of non-forest communities for**

biological conservation. New Zealand Journal of Botany. 30: 163-179.

The authors recommend a height-frequency method of vegetation sampling for monitoring composition and structure of tussocklands and similarly structured vegetation types. They applied this method on 7 natural areas in New Zealand, and for one site compared data with transect data collected 16 years earlier. Five 100m or 50m transects were established and permanently monumented. The sampling frame consisted of successive, open-ended vertical sampling cubes spaced 6cm apart to provide a volume of 100 cm^3. A braided cord, marked with sampling intervals, was placed at canopy height. For consistency in height measurements, the frame was attached to a 5cm graduated metal stake. Species presence and height were recorded by 5cm intervals within each 100 cm3 sample. Data analysis included computation of species importance values based on a single summed height-frequency value. This summed value corresponded to a species total frequency in all height categories for the entire transect. This value was also considered an index of biomass. Species with a biomass index value >4 were diagrammatically represented. Multivariate clustering procedures (TWINSPAN) were also applied to the summed height-frequency data. The authors also tested for: 1) adequacy of sample size of 100 points along each transect; 2) adequacy of method for measuring changes over time; and 3) consistency in readings with different observers. The authors conclude by suggesting this method provides a reliable and standardized method to monitoring community composition and structure of non-forested vegetation types over time.

herbaceous species, long-term ecological monitoring, natural areas,. baseline monitoring, permanent plots, grassland, community structure, community composition, heights, multivariate analysis, sampling design, observer variability, frequency, precision, detecting change, biomass.

318. Diersing, V. E.; Shaw, R. B.; Tazik, D. J. 1992. **U.S. Army land condition-trend analysis (LCTA) program**. Environmental Management. 16: 405-414.

monitoring examples, agency plans, ecological monitoring programs, monitoring overviews.

319. Diggle, P. J. 1988. **An approach to the analysis of repeated measures**. Biometrics. 44: 959-971.

analysis, repeated measures analysis.

320. Diggle, P. J. 1975. **Robust density estimation using distance methods**. Biometrika. 62: 39-48.

The bias of distance measures to measure density in aggregated and regular populations is well known. Here, a method robust to spatial distribution is developed that uses two distance measures biased in opposite directions.

field techniques, distance methods, nearest neighbor, density.

321. Dix, R. L. 1961. **An application of the point-centered quarter method to the sampling of grassland vegetation**. Journal of Range Management. 14: 63-69.

The point-center quarter distance method was applied to sampling grassland vegetation by measuring the distance from the sampling point to the nearest shoot. The method is described and a data sheet example provided. It was tested on 3 grassland stands in North Dakota. Sampling adequacy, defined as the 30 measurements per species suggested by Cottam and Curtis (1956), was relatively easy to achieve for the two or three major species, but rarer species would require a large number of sampling points in order to encounter 30 individuals. The author recognized that the likely non-random distribution of individuals would result in an erroneous estimate of actual density, but suggested that in the absence of other rapid field methods, the point-center quarter values could serve as an index for use in monitoring. Sampling could be done at a rate of 37 to 67 sampling points per hour in this vegetation.

community-level, field techniques, community composition, rangeland, grassland, distance methods, density, point-center methods, community change.

322. Dixon, P. M.; Garrett, K. A. 1993. **Sampling ecological information: choice of sample size reconsidered**. Ecological Modelling. 68: 67-73.

The authors refute the conclusions of Dale and others (1991) that: 1) sample size should be such that the standard error to mean ratio less than 0.1 and skewness and kurtosis fall within a certain range; 2) a larger sample size is required from non-normal populations; and 3) sample means from log-normal distributions are biased. They point out conclusion (3) is based on only 2 simulations, which could result in bias by chance. In addition, sampling theory states that the mean is unbiased regardless of skewness and kurtosis, as long as samples are taken from the population randomly. They demonstrate this using computer simulations of 1000 replicates from the 4 data distribution types evaluated by Dale and others (1991) They conclude both statistical theory and simulation suggest skewness and kurtosis have no affect on the variance of the sample mean; the results of Dale and others (1991) stem from the higher population variances associated with their skewed populations, not because of any inherent characteristic of skewness or kurtosis. Because of these erroneous conclusions, the recommendation of Dale and others (1991) for sample size inflates the required sample size. The standard error/mean ratio is recommended for use when the variability increases with the mean. Alternately, the acceptable precision could be specified, based on the objectives of the study, the costs of statistical error, and the resources available for the work. The authors conclude with a warning against the use of computer simulations for exploring situations for which exact or theoretical solutions already exist, and against basing conclusions on only a few simulated replicates.

design, sample size, precision, sampling design, confidence intervals, analysis.

323. Dixon, W. J.; Massey, F. J. 1983. **Introduction to statistical analysis. 4th ed.** New York, NY: McGraw-Hill. 678 p.
statistics overview, analysis.

324. Dobelbower, K. R.; Zeide, B. 1981. **Diagonal plots for arid land resource inventories**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 431-434.
Square timber volume plots were more efficiently measured than circular plots because borderline trees could be rapidly checked. Eleven trees were mistakenly included and 4 excluded on circular plots, compared to 5 and 2 trees on square plots. The square plots were rapidly established by measuring the diagonals and the right angles between the diagonals. Detailed directions and equipment lists are provided for both methods.
inventory, sampling design, plot dimensions, observer variability, tree, basal area, DBH, density, field techniques.

325. Dodd, M. E.; Silvertown, J.; McConway, K.; Potts, J.; Crawley, M. 1995. **Community stability: a 60 year record of trends and outbreaks in the occurrence of species in the Park Grass Experiment**. Journal of Ecology. 83: 277-285.
long-term ecological monitoring, permanent plots, natural variability, community-level, community change.

326. Donoghue, D. N. M.; Shennan, I. 1987. **A preliminary assessment of Landsat TM imagery for mapping vegetation and sediment distribution in the Wash Estuary**. International Journal of Remote Sensing. 8: 1101-1108.
remote sensing, Landsat, TM, vegetation mapping, community-level.

327. Driscoll, R. S. 1958. **A loop method for measuring ground cover characteristics on permanent plots**. Journal of Range Management. 11: 94.
A simple sampling frame for loop sampling was created from a board suspended parallel to the ground from rings at the ends of two chaining pins. Notches in the board guided the horizontal and vertical positioning of the loop sampler along the board.
field techniques, canopy cover, cover, point intercept, point frames, loop frames, tools, permanent plots.

328. Driscoll, R. S.; Frayer, W. E.; Werth, L. F. 1983. **Complexities of remote sensing with sampling for change detections**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 613-617.
An overview of Landsat imagery and aerial photography is presented. While the technology has improved since the date of this paper, the overview remains current because many of the methods are still in use. It is especially helpful for projects using older imagery systems. Both Landsat and aerial images can be effective for monitoring when coupled with a ground survey. The images can be used to stratify sampling areas, resulting in a significant reduction in ground sampling units needed to achieve the same precision as simple random sampling.
aerial photography, Landsat, MSS, remote sensing.

329. Drost, C.; Stohlgren, T. J. 1993. **Natural resource inventory and monitoring bibliography**. Tech. Rep. NPS/WRUC/NRTR-93/04. Davis, CA: U.S. Department of Interior, National Park Service, Cooperative Park Studies Unit, University of California.
This bibliography contains some references on vegetation monitoring accessible from the key word list. Some of the references include short annotations.
inventory, monitoring overviews.

330. Duffy, D. C.; Meier, A. J. 1992. **Do Appalachian herbaceous understories ever recover from clearcutting?** Conservation Biology. 6: 196-201.
Authors compared 9 sites sampled with ten to twenty-four plots (1m²) in primary (old growth) forests with plots in successional forests of similar elevation, exposure, soil, slope, and geology. Plots were placed randomly, but rhododendron stands were excluded. Plots were measured for cover using a modified Daubenmire scale. Number of species per 1m² plot was used as an index of species richness and total herbaceous cover as an index of abundance. Richness and cover of understory herb species in secondary forests of 50 to 85 years of age were less than that of primary forests. The authors suggest that understory herb species may be among forest organisms most sensitive to clear-cutting or other types of disturbance. Note that this paper received widespread media attention and comments by Elliot and Loftis (1993).
community-level, field techniques, general examples, herbaceous species, indicators, disturbance, vegetation treatments, community composition, community change, species richness, succession, species diversity, predicting change, cover classes, canopy cover, plot selection, plot dimensions.

331. Duffy, J. J.; Luders, G.; Ketshcke, B. 1981. **Cost-benefit optimization for biota monitoring programs**. In: Jensen, L. B., ed. Issues associated with impact assessment. Sparks, MD: E. A. Communications: 135-147.
monitoring overviews, design.

332. Duinker, P. N. 1989. **Ecological effects monitoring in environmental impact assessment: what can it accomplish?** Environmental Management. 13: 797-805.

Monitoring is defined as repetitive measurement of quantitative data on the condition of a variable of interest over time for a defined purpose. In Environmental Impact Assessment (EIA) monitoring, the primary reason for monitoring is to address the uncertainty associated with the EIA predictions. It is impossible to measure the impacts directly, since impacts are the difference between the condition of the resource or variable with and without the action (power plant, clear cut, etc.). What must be measured is the difference between two time series, one with the impact and a predicted time series for the same system without the impact. These predictions are critical, since good monitoring design requires the development of hypotheses, which are predictions on the direction and variability of the changes expected. Baseline measurements, while providing some indication of potential range of variability, are generally inadequate because of the lack of accompanying information on the causes of variability, which are needed in order to build process-based forecasting models. Monitoring that simply compares the state of a variable before and after impact, even a design which incorporates several years of measurement before and after, is inappropriate because it assumes that the baseline state would remain constant in the absence of the intervention. The author also discounts designs that utilize controls because of the absence of truly similar systems to use as controls. Recommended as an alternative is the use of process-based models, which are based on explicit quantitative hypotheses about how a system is structured and how it functions. The model is tested by comparing the model-generated expectation of system performance with actual performance measured through monitoring.

sampling design, ecological models, monitoring and management, objectives, predicting change, detecting change, monitoring definitions.

333. Duinker, P. N.; Baskerville, G. L. 1986. **A systematic approach to forecasting in environmental impact assessment**. Journal of Environmental Management. 23: 271-290.

ecological models, monitoring and management, predicting change.

334. Duinker, P. N.; Beanlands, G. E. 1986. **The significance of environmental impacts: an exploration of the concept**. Environmental Management. 10: 1-10.

design, monitoring and management, analysis, power, precision, Type I and Type II errors.

335. Durr, P. C.; Richmond, L.; Eagar, C. 1988. **Site classification and field measurements: methods manual**. Gatlinburg, TE: U.S. Department of Interior, National Park Service, Great Smoky Mountains National Park.

monitoring examples, field techniques.

336. Dutilleul, P. 1993. **Spatial heterogeneity and the design of ecological field experiments**. Ecology. 74: 1646-1658.

Spatial heterogeneity must be considered in the planning of ecological field experiments. This paper briefly reviews concepts in experimental design (replication, randomization, control, and interspersion) and discusses the value of several standard block designs for dealing with spatial heterogeneity. Approaches to sampling in systems with three pattern types (small scale heterogeneity, patches, and gradients) are described and illustrated with examples. The author offers the following conclusions: 1) effective design requires some knowledge of the nature of the pattern in the area being sampled; 2) randomized (complete or incomplete) blocks is recommended as a means of dealing with spatial heterogeneity; 3) where sites are heterogeneous in two directions, the Latin square design is especially appropriate; and 4) a completely randomized approach should only be applied when the site is homogeneous at large scale.

experimental design, random sampling, sampling design, plot selection.

337. Dyer, M. K.; Crossley, D. A. 1986. **Coupling of ecological studies with remote sensing: potentials at four biosphere reserves in the United States**. Man and the Biosphere Publ. 9504. Washington, DC: Department of State. 143 p.

monitoring examples, large-scale monitoring, remote sensing.

338. Eberhardt, L. L. 1976. **Quantitative ecology and impact assessment**. Journal of Environmental Management. 4: 27-70.

This paper reviews monitoring in impact assessment. The unifying theme is that identifying changes due to human action in natural systems is extremely difficult. General suggestions are: 1) use a regional approach to determine cumulative changes rather than trying to measure the very small changes associated with individual projects; 2) replace poorly define concepts such as "health," which is biased toward the individual rather than the population, with more measurable ones such as productivity; and 3) recognize the potential for framing the question so that standard experimental designs can be used, such as determining differences in density between the impact site and an unimpacted site. The Before-After-Control-Impact (BACI) model is described for situations requiring causal proof, but a discussion and example of a typical required sample size suggests that this experimental design may not be applicable in many situations. A common problem is that a long post-project monitoring period more strongly reflects long term trends at impact and control sites, rather than providing a comparison to the baseline ratios. Pilot studies are critical, not only for determining the variability and the needed sample size, but for exhibiting the cost of data collection and the limitations on sample size. The author then reviews available methods for estimating density. Most of these are

relevant only to animals, but a few are applicable to plants. Important observations are: 1) Where the sampling unit is the individual (a single plant), it is very difficult to gain a random sample. Using the nearest individual to random points is biased in favor of choosing isolated individuals. The best approach is one of subsampling in which all the individuals or a sample of them within a quadrat are counted. 2) When plants are aggregated, long narrow plots are more advantageous than square ones because of averaging of clumps and intervening empty space. 3) Point methods or distance methods should be generally avoided becaue of their dependence on random distribution of individuals. 4) Diversity indices have not been evaluated for sampling variability; most assume a random selection of individuals from the population, but most plants are sampled in quadrats as clusters of individuals.

community-level, monitoring overviews, community composition, species richness, diversity indices, species diversity, distance methods, density, community change, pilot study, BACI, sampling design, plot dimensions.

339. Eberhardt, L. L. 1967. **Some developments in "distance sampling."** Biometrics. 23: 207-216.

Most distance methods are applicable only to populations in which individuals are randomly distributed over an indefinitely large area. In real populations, this is usually not the case; most biological entities are distributed in a non-random fashion. In this paper, the author describes sampling distributions of the distance from a randomly located point to the nearest individual for individuals distribued in space in regular and contagious patterns. A new index of nonrandomness, based on the coefficient of variation, is proposed and demonstrated using three published data sets.

field techniques, density, distance methods, nearest neighbor.

340. Eberhardt, L. L.; Thomas, J. M. 1991. **Designing environmental field studies.** Ecological Monographs. 61: 53-73.

In this often-cited paper, eight types of field studies are classified. In situations where the treatment can be controlled by the observer, three types of field studies are defined: 1) replicated experiments, 2) unreplicated experiments, and 3) sampling for models. Situations with uncontrolled perturbations (4) such as a fire, will be similar to an unreplicated experiment. When the perturbation is not obvious, the study can involve observational studies of a particular subset of the area of interest (5). If sampling involves the entire area, three types of sampling can be distinguished: 6) analytical sampling that compares subsets of the entire population to look at hypothesized differences; 7) sampling to describe the entire population; and 8) sampling to identify patterns. Common errors that surface in the application of all eight types are inadequate sample size and pseudoreplication (subsampling used as replication).

objectives, sampling design, experimental design, replication, pseudoreplication.

341. Eckblad, J. W. 1991. **How many samples should be taken?** BioScience. 41: 346-348.

Given a pilot study in which an estimate of the sample mean and variance is found, the sample size required for a chosen precision can be calculated. The author describes methods for calculating sample size, and recommends graphing percent precision of the mean (e.g., within 10%) against the number of samples required. This provides a visual portrayal of the trade-offs during sampling design.

design, analysis, objectives, sample size.

342. Eddelman, L. E.; Remmenga, E.; Ward, R. 1964. **An evaluation of plot methods for alpine vegetation.** Bulletin of the Torrey Botanical Club. 91: 439-450.

Several sampling designs were compared in an area of homogeneous tundra vegetation in the Colorado Rockies. Densities of 3 forb species and 4 graminoid species were measured in 100 of the following sized plots: 10x10cm, 20x20cm, 40x40cm, 5x20cm, 10x40cm, 20x40cm, 20x80cm and a 400cm^2 circle. All plots were distributed randomly throughout a 30x20m sampling area. Plots were also distributed in a restricted random sampling design in which the sampling area was divided into 10 equally sized blocks and 10 sampling units were randomly placed within each block. Efficiency was evaluated in terms of hours required to sample the seven species to estimate density within a 10% standard error of the mean. In general, the rectangular plots performed better than square ones. The two largest were best, but had the disadvantage of 100% frequency for some species, precluding their use for frequency analysis. Only 200 of the 20x80cm plots were required to estimate density to the desired precision, compared to over 4700 of the 10x10cm plots. Small plots also provided estimates of density on a per area basis that were as much as twice those of the larger plots, likely because of bias in boundary decisions. No consistent improvement was achieved by using restricted random sampling.

community-level, design, field techniques, community composition, alpine, meadow, density, frequency, sampling design, plot dimensions, random sampling, sample size.

343. Edmunds, S. W. 1981. **Desert land use planning based upon field sampling and remote measures**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 317-322.

Designing effective inventories requires the uses of the data be identified in the design phase. In this paper, two examples of land use planning, one for geothermal development in an agricultural/urban area and the other in the wilderness of the California Desert are used to illustrate the design of inventory to meet specific planning needs and

objectives. Both efforts made extensive use of aerial photography.

landscape-level, pattern, landscape planning, objectives, ecosystem management, inventory, large-scale monitoring, integrated monitoring, remote sensing, aerial photography.

344. Edwards, D.; Coull, B. C. 1987. **Autoregressive trend analysis: an example using long-term ecological data**. Oikos. 50: 95-102.

A time series analysis using autoregressive integrated moving average (ARIMA) models is illustrated using a 10-year data set of monthly abundances of benthic organisms. Errors associated with time series data are not independent; correlation decreases as the time between measurements increases. The result is that normally applied tests of significance will be invalid and usually too liberal. Autoregressive trend analysis addresses the two components of variability -- the "fresh" variability associated with each new observation, and the "leftover" variation from previous observations. The authors conclude that this technique may be useful in designing and analyzing long-term ecological studies. An analysis of the variability in an existing data set can identify the loss in precision that will occur given a reduction in sampling intensity (from, for example, weekly observations to monthly).

monitoring examples, analysis, long-term ecological monitoring, time series, trend analysis.

345. Efron, B.; Tibshirani, R. 1993. **Introduction to the bootstrap**. New York, NY: Chapman and Hall. 436 p.

statistics overview, analysis, bootstrap, randomization tests.

346. Elliot, K. J.; Loftis, D. L. 1993. **Vegetation diversity after logging in the southern Appalachians**. Conservation Biology. 7: 220-221.

This letter critiques a paper by Duffy and Meier (1992) which concluded species diversity was less in logged forests compared to old growth. Elliot and Loftis argue that estimating species richness as a per plot average is affected by population size and plot size, and is further complicated when individuals are not randomly dispersed. The fact that Duffy and Meier (1992) avoided Rhododendron patches biases their sample. They further argue that since Duffy and Meier (1992) only sampled once during the season (early spring), many species could have been missed that would have invalidated their results. Duffy provides a response. He argues that their first point, while true, is not important in this study because the pattern would remain consistent unless there was greater difference between plots in second growth forests than in old growth forests. To the second point concerning Rhododendron patches, he argues that these patches could be considered a different community, and that excluding them from the sample while sampling the remaining areas randomly does not bias the sample. To the last argument, he responds that the focus of this study was spring herbs and suggests testing the hypothesis that the pattern observed for spring ephemerals is offset by higher diversity of later season species in secondary forests. This issue of Conservation Biology has an additional exchange on this subject that is not reviewed here. The original paper and the subsequent exchanges illustrate the management implications of biodiversity research (and monitoring) and the importance of good design.

monitoring and management, resource management, biodiversity, disturbance, landscape change, indicators, patch dynamics, community composition, landscape-level, community-level.

347. Ellison, A. M. 1993. **Exploratory data analysis and graphic display**. In Scheiner S. M.; Gurevitch J., eds. Design and analysis of ecological experiments. New York, NY: Chapman and Hall: 14-43.

Before beginning formal statistical analysis, graphical approaches can be used to explore patterns in the data. Several types useful for different kinds of data or expected patterns are illustrated (histograms, stem and leaf plots, box-and-whisker plots, fuzzygrams, probability plots, scatterplots, convex hull, scatterplot matrices, and others). Graphics are also useful for communicating large amounts of information clearly and concisely. Unfortunately, with the advent of greater sophistication in computer graphics capabilities, extravagant complicated figures ("chartjunk") are becoming more common. These, the author contends, compromises the value of graphics by obscuring the message with unecessary frills. Guidelines for clear effective graphics are given (e.g., emphasize data, watch for obscured data points, avoid use of reference lines, and create distinguishable overlapping points).

graphical analysis, analysis, statistics overview.

348. Ellison, A. M. 1996. **An introduction to Bayesian inference for ecological research and environmental decision-making**. Ecological Applications. 6(4): 1036-1046.

analysis, Bayesian statistics, statistical interpretation.

349. Ellison, A. M.; Bedford, B. L. 1995. **Response of a wetland vascular plant community to disturbance: a simulation study**. Ecological Applications. 5: 109-123.

A spatial computer simulation model was developed by aggregating species into functional groups, and used to investigate the responses of plant communities to changes in hydrology. The results of the model are in rank agreement with seven years of observed changes in a sedge meadow and adjacent shallow marsh.

community-level, objectives, wetland, predicting change, ecological models, disturbance, functional groups.

350. Ellison, L. 1942. **A comparison of methods of quadrating vegetation**. Journal of Agricultural Research. 64: 595-614.

field techniques, technique comparison, density, charting.

351. Engeman, R. M.; Sugihara, R. T.; Pank, L. F.; Dusenberry, W. E. 1994. **A comparison of plotless density**

estimators using Monte Carlo simulation. Ecology. 75(6): 1769-1779.

Twenty-five plotless density estimators were compared to quadrat sampling using computer simulation. The estimators that performed the best involved measurements to the third closest individual or measures to nearest plant, nearest neighbor, and nearest individual to nearest neighbor.

community-level, community composition, coniferous forest, deciduous forest, forest, woodland, shrubland, field techniques, angle-order, distance methods, nearest neighbor, point-center methods, random pairs, density, technique comparison.

352. Enright, N. J. 1982. **Recognition of successional pathways in forest communities using size-class ordination**. Vegetatio. 48: 133-140.

succession, community-level, forest, tree, ecological models, objectives, multivariate analysis, analysis.

353. Eshelman, K. R. 1983. **Vegetation monitoring and inventory on the public land**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 79-83.

Frequency sampling is widely used on Bureau of Land Management Lands. Approximately 60% of the field offices were using frequency data as the primary indicator of change in 1983. Several methods in common use are reviewed here.

field techniques, community-level, frequency, detecting change, desert, rangeland, shrubland, agency guidance and policy.

354. Evans, R. A.; Jones, M. B. 1958. **Plant height times ground cover versus clipped samples for estimating forage production**. Agronomy Journal. 50: 504-506.

Individual plant heights were measured along a step-point transect and cover of each species estimated in four 1x1ft sampling units. The values were averaged and then multiplied to give a height x ground cover value (HG). This was compared to 3 types of clipping designs: a single 1x1ft plot, 3 clipped plots that had been averaged, and a 33ft^2 clipped plot. A total of 704 comparisons were made under several treatment conditions and at three phenological stages. Correlation of the HG value with clipped estimates ranged from 29% to 98%. Correlation was better for the larger clipped samples (74%). The HG method provided good estimates of composition and production (although not expressible in standard lbs/area) more rapidly than clipping. Total vegetation biomass, however, was more effeciently estimated by clipping.

field techniques, production, community composition, canopy cover, cover, biomass, heights, technique comparison, canopy volume, community-level.

355. Evans, R. A.; Love, R. M. 1957. **The step-point method of sampling: a practical tool in range research**. Journal of Range Management. 10: 202-203.

This paper describes the step-point method of sampling cover and vegetative composition, a method widely adopted by resource management agencies in the 1960s and early 1970s. At each step point, a single sampling pin is lowered to the ground, guided by a notch in the toe of the investigator's boot, which is held at a 30° angle to the ground. The method obviously works best on sites with short vegetation that will not be disturbed by the boot. If no vegetation is contacted by the pin, the nearest plant in a forward 180° arc is recorded. The authors argue that this latter feature is especially necessary in sparse vegetation, where many sampling points would be required to afford a reasonable number of hits on vegetation. These data are supplemented by an ocular estimation of ground cover in a 1x1ft frame subdivided into four 6x6in quadrants. The authors recommend that cover be estimated at 8% to 10% of the point sampling locations. Eight teams of samplers sampling the same area gave fairly comparable results. Samples of 100 step-points resulted in similar composition values as 500 point-intercepts but required only 15% to 20% of the time.

field techniques, cover, community composition, rangeland, ocular estimation, point intercept, canopy cover, cover classes, observer variability, technique comparison, community-level.

356. Everitt, B. 1978. **Graphical techniques for multivariate data**. London: Heinemann. 117 p.

analysis, graphical analysis, multivariate analysis.

357. Everitt, J. H.; Richardson, A. J.; Escobar, D. E.; Villarreal, R. 1992. **Mapping native plant communities with color-infrared video imagery**. 12th biennial workshop on color aerial photography and videography in plant science and related fields; Orlando, FL. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 30-37.

Spectral classification of plant communities demonstrated only limited success when compared to existing plant community maps prepared by field mapping.

vegetation mapping, community-level, remote sensing, video, field techniques.

358. Everson, T. M.; Clarke, G. P. Y.; Everson, C. S. 1990. **Precision in monitoring plant species composition in montane grasslands**. Vegetatio. 88: 135-141.

grassland, herbaceous species, community composition, community change, community-level, design, precision.

359. Ewing, K.; Doborowlski, J. P. 1992. **Dynamics of shrub die-off in a salt desert plant community**. Journal of Range Management. 45: 194-199.

community change, community-level, field techniques, shrubland, desert, density, permanent plots, community structure, general examples.

360. Fairweather, P. G. 1993. **Links between ecology and ecophilosophy, ethics and the requirements of environmental management**. Australian Journal of Ecology. 18: 3-19.

Values and environmental ethics will affect the way monitoring programs are designed and data analyzed. In any project, including environmental analysis and environmental audit (monitoring) situations, there is potential for error and uncertainty. To whom the advantage of this uncertainty goes, and conversely where burden of proof is placed (prove that there is no harm to the environment or prove that there is) is decided by values and ethics, not by the science of ecology. Similarly, because ecosystems are dynamic, variable, and poorly understood, defining the desired "natural" state and objective is difficult, and usually is based on values and perceptions. It is the task of ecologists to determine the range of natural variability and the level of change that can be attributed to anthropogenic causes. This is done through various types or stages of monitoring: estimating normal range of variation, predicting impact based on pilot data, evaluating changes due to the activity, and incorporating a feedback loop to influence continued activity or implementation of similar activities at other sites. The author identifies key questions that monitoring seeks to answer: Does an impact exist? What is its magnitude and spatial extent? Are there trends over time? Is recovery possible? Each of these requires a different design. Ultimately, the purpose of monitoring must be to change human activities to better conserve the environment. Monitoring without action is a waste of time and resources. Similarly, monitoring that is not effectively designed to measure unacceptable levels of impact is of little value; thus, analysis of the power of monitoring designs is critical.

monitoring overviews, adaptive management, feedback loops, monitoring and management, objectives, predicting change, detecting change, power, design, natural variability.

361. Fairweather, P. G. 1991. **Statistical power and design requirements for environmental monitoring**. Australian Journal of Marine and Freshwater Research. 42: 555-567.

This paper is one of the best overviews available on the importance of power considerations (Type II error) in environmental monitoring. The paper reviews the literature pertinent to power analysis in environmental monitoring, providing a table of citations by subject. A clear explanation and simple example are provided showing that real and biologically significant changes may be occurring but are missed because of low power. In environmental monitoring, the Type II error is critical, because real environmental degradation could be taking place but remain undetected by the monitoring design. Power analysis is important at three stages in environmental monitoring. It can be used after a pilot period to better design monitoring studies by identifying the number of samples needed to detect desired size effects with the desired probability. Power analysis can also aid in choosing which statistical tests are preferable, because they vary in power. Finally, power analysis can be used after a study yields nonsignificant results to evaluate whether the study was powerful enough to conclude there truly is no effect. A key problem in monitoring is that as the effect magnitude declines, the number of samples required to detect that effect rises. Thus studies with adequate power are often very expensive. In effect, this places the advantage with potential polluters; it is more likely real effects will be missed than false effects assumed (Type I error). In actuality, Type I errors are probably less costly than Type II errors in environmental monitoring. The first can result in false alarms, and possible delay of the activity, but are usually quickly detected by additional testing. Type II errors are an undetected cost to the environment, and may provide a false sense of security until the resource completely collapses and extreme and expensive recovery costs are incurred.

design, power, sampling design, detecting change, objectives, sample size, Type I and Type II errors.

362. Faisal, K. T.; Fisser, H. G.; Ries, R. E. 1983. **Technical notes: a modified 100-point frame for vegetation inventory**. Journal of Range Management. 36(1): 124-125.

This technical note explains how to construct a modified point frame which was developed for sampling short-grass prairie vegetation. The frame is made from aluminum angle, steel welding rods, brass pipe fittings, steel tubes, and rubber O-rings. The point frame allows recording 100 point hits within a 30x60cm quadrat. Instructions for using the frame are also provided.

field techniques, inventory, point intercept, cover, tools, point frames.

363. Faith, D. P.; Dostine, P. L.; Humphrey, C. L. 1995. **Detection of mining impacts on aquatic macroinvertebrate communities: results of a disturbance experiment and the design of a multivariate BACIP monitoring program at Coronation Hill, Northern Territory**. Australian Journal of Ecology. 20: 167-180.

design, BACI, detecting change, power, precision, Type I and Type II errors, monitoring examples, aquatic.

364. Faith, D. P.; Humphrey, C.; Dostine, P. 1991. **Statistical power and BACI designs in biological monitoring: comparative evaluation of measures of community dissimilarity based on benthic macroinvertebrate communities in Rockhole Mine Creek, Northern Territory, Australia**. Australian Journal of Marine and Freshwater Research. 42: 589-602.

The BACIP (Before After Control Impact Pairs) monitoring design was evaluated in an area of historic mining activities. In this design, at each sampling period the difference between a paired control and impact site is measured. For this study, the difference was characterized in terms of community differences using dissimilarity measures. The purpose is to look for a significant change in the mean differences of the series taken before and after perturbation or impact. Because the monitoring design was to be used in a high-value ecological area, a key concern in the design was

the power of the test to detect even small changes. Power is increased through temporal replication (a large number of paired observations before and after), thus the main purpose of this study was to determine the number of years needed to achieve adequate power. In this initial report, two years of data on abundances of benthic macroinvertebrate communities were used as a pilot study to test the efficiency of a number of dissimilarity measures. Of the eight measures tested (Bray-Curtis, Canberra, Manhattan, Euclidean, Intermediate, Kendall, Kulczynski, and Chi-squared), the Bray-Curtis measure was most sensitive.

community-level, design, similarity measures, multivariate analysis, community change, power, detecting change, pilot study, BACI, sampling design, aquatic.

365. Faith, D. P.; Minchin, P. R.; Belbin, L. 1987. **Compositional dissimilarity as a robust measure of ecological distance: a theoretical model and computer simulations**. Vegetatio. 69: 57-68.

In this paper, a number of similarity measures are compared for robustness to noise and their resulting response patterns in ordinations.

analysis, community composition, community-level, similarity measures, multivariate analysis, ordination.

366. Falkengren-Grerup, U. 1995. **Long-term changes in flora and vegetation in deciduous forests of southern Sweden**. Ecological Bulletin. 44: 215-266.

long-term ecological monitoring, deciduous forest, community change, community-level, natural variability.

367. Falkner, E. 1994. **Aerial mapping**. Boca Raton, FL: Lewis Publishers. 352 p.

This book describes manual and computer-aided mapping from aerial photographs and satellite imagery. Included is a section on global positioning system surveying, orthophotography, and an introduction to remote sensing systems and image analysis. About a third of the book describes mapping project design and cost estimation, including three hypothetical exercises.

aerial photography, Landsat, MSS, TM, SPOT, remote sensing, GIS.

368. Farnsworth, E. J.; Rosovsky, J. 1993. **The ethics of ecological field experimentation**. Conservation Biology. 7: 463-472.

While directed primarily at ecologists who work with animals, many of the concepts in this paper are also applicable to plant ecologists. The authors note there are specific examples of the explicit consideration of ethical issues in field experiments, but there is no cohesive or comprehensive code of ethics to which all ecologists subscribe. They suggest that four factors have discouraged a public discussion: 1) avoidance of an emotional debate; 2) an assumption that the benefits outweigh the short-term costs; 3) the difficulty in perceiving negative effects; and 4) the occurrence of "natural" perturbations makes experimental ones unnecessary. Programs such as the Sustainable Biosphere Initiative illustrate that ecologists are beginning to recognize they have responsibility to pursue integrated basic and applied research that will ultimately promote the conservation of study sites and species.

special sites, objectives, monitoring overviews, reference areas, natural areas.

369. Farrell, R. 1980. **Methods for classifying changes in environmental conditions**. Tech. Rep. VR-EPA7, 4-FR80-1. Ann Arbor, MI: Vector Research Incorporated.

detecting change, objectives, monitoring and management.

370. Ferris-Kann, R.; Patterson, G. S. 1992. **Monitoring vegetation changes in conservation management of forests**. Bull. 108. Farnham, Surrey, England: Forestry Commission. 31 p.

This publication is one of few that provides advice on setting objectives and selecting appropriate parameters for monitoring. The authors define monitoring as simply the detection of extent and direction of change, (noting that monitoring can rarely show causes of change) and focus on simple methods that can be implemented by forest staff with basic field skills. In the section on objectives, the importance of specific targets for monitoring is stressed (e.g., achieve a mean cover of at least 20% of flowering plant species on road verges). The authors recommend that key features and characteristics of vegetation be identified during the design phase, and methods specifically developed to monitor these, rather than an approach that uses field surveys and accumulation of data in the search for significant statistical results. Other chapters describe: 1) sampling approaches; 2) available types of vegetation measures, their advantages and disadvantages, and the kinds of vegetation they are appropriate to; 3) simple analyses of data; and 4) suggested sampling designs for linear habitats, woodlands, and patchy environments. Although this guide is fairly short, it provides an excellent overview and introduction and is well-referenced.

general book on monitoring, monitoring and management, objectives, community composition, community change, coniferous forest, deciduous forest, density, distance methods, plotless methods, canopy cover, cover classes, line intercept, point frames, point intercept, ocular estimation, frequency, field techniques, tree, cover, community-level, monitoring definitions.

371. Fiedler, P. L.; Jain, S. K., eds. 1992. **Conservation biology - the theory and practice of nature conservation, preservation and management**. New York, NY: Chapman and Hall. 495 p.

special sites, monitoring and management, landscape-level, natural areas, scale, ecosystem management.

372. Field, D. I.; Glatzle, A. 1978. **Monitoring the Kalahari Desert**. In: Hyder, D. N., ed. Proceeding of the 1st

International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 193-197.

This paper describes the development of a large-scale monitoring program for the natural rangeland of Botswana. The objectives of the monitoring program were to detect the following negative changes: increase in bare ground, encroachment of woody plants, and undesirable changes in the composition of the herbaceous layer. Baseline studies were established at 50 sites throughout the country. Sites were chosen to represent the main vegetation types and to take advantage of supplementary information such as known grazing intensities and the relation of the sites to watering points. Criteria in the development of the method included consideration of statistical design, accurate measurement of trends, robustness to different observers, and time costs. The method chosen was a modified Parker three-step. Six 25m transects were laid out as three spokes of a wheel. Point intercept cover was measured along these transects by 500 points for basal cover and 100 points for canopy cover. Density was measured in five 30x30cm plots per transect. Six 20x10m plots were established at the site for measurement of woody plant density. The changes detected by the monitoring design over 3 years are presented.

community-level, landscape-level, monitoring examples, field techniques, cover, rangeland, shrubland, community change, long-term ecological monitoring, large-scale monitoring, permanent plots, frequency, point intercept, density.

373. Finney, D. J. 1950. **An example of periodic variation in forest sampling**. Forestry. 23: 96-111.

design, systematic sampling, random sampling, sampling design.

374. Finney, D. J. 1948. **Random and systematic sampling in timber surveys**. Forestry. 22: 64-99.

sampling design, systematic sampling, random sampling, design.

375. Fiorella, M.; Ripple, W. J. 1993. **Analysis of conifer forest regeneration using Landsat Thematic Mapper data**. Photogrammetric Engineering and Remote Sensing. 59: 1383-1388.

coniferous forest, forest, tree, remote sensing, Landsat, TM, succession.

376. Fiorella, M.; Ripple, W. J. 1993. **Determining successional stage of temperate coniferous forests with Landsat satellite data**. Photogrammetric Engineering and Remote Sensing. 59: 239-246.

coniferous forest, forest, tree, remote sensing, Landsat, TM, succession.

377. Fisser, H. G. 1961. **Variable plot, square foot plot and visual estimates for shrub crown cover measurements**. Journal of Range Management. 14: 202-207.

The three methods of estimating cover were each used by three observers on a saltsage site (well defined plants usually under 0.3m tall), a big sagebrush site (shrub canopy poorly defined and up to 0.8m tall) and a greasewood site (shrubs very poorly defined and up to 1.3m tall). Visual estimation was consistent for the three observers on the saltsage site, but highly variable on the other sites. Cover was also measured in ten plots placed along a transect. These were 1x1ft, subdivided into 144 squares, each counted for bare ground or shrub cover. This method gave the lowest cover value, and was highly variable between observers (note that plots were located independently by each observer). Variable plots worked well, but smaller angles (which results in a larger sampling radius) consistently underestimated cover in the taller vegetation. Observer height also had an effect.

field techniques, shrub, cover, ocular estimation, variable plots, canopy cover, shrub grassland, shrub, observer variability, technique comparison.

378. Fisser, H. G.; VanDyne, G. M. 1966. **Influence of number and spacing of points on accuracy and precision of basal cover estimates**. Journal of Range Management. 19: 205-211.

Point intercepts are actually small circular plots with an area defined by the diameter of the pin. This results in overestimation of the true cover. The authors used the intercept of a 0.01ft length of tape, which lacked breadth, and assumed this approached a true point. They sampled grassland vegetation with 350 transects (5ft long), each with 500 intercept units. From this population of points, 6 samples were drawn: 3 random of 25, 50 and 100 units from each transect and 3 systematic samples of the same number of units. The number of point transects and line intercept transects needed to yield an estimate of cover within 10% of the mean with a 95% confidence was calculated. The 350 transect sample was adequate only for all live vegetation and all grasses. Point sampling required more than 350 lines (up to 2 to 5 times as many for most species) but many fewer points per line. Systematic point sampling gave higher frequencies for a rhizomatous species but lower frequencies for bunchgrasses and forbs compared to random sampling. Two key practical applications are that points should be more widely spaced than the average diameter of the plant and that greater sampling efficiency occurs with fewer points and more lines.

field techniques, herbaceous species, meadow, grassland, canopy cover, cover, line intercept, point intercept, technique comparison, precision, random sampling, systematic sampling, sampling design, design.

379. Fisser, H. G.; VanDyne, G. M. 1960. **A mechanical device for repeatable range measurements**. Journal of Range Management. 13: 40-42.

Directions for constructing a device to increase accuracy of remeasured permanent line intercept transects and reduce observer bias are presented. The device measures transects up to 5ft long with a sliding arm on a rigid bar. A tripod

assembly at each end fits over permanent field markers so the transect can be exactly relocated.

field techniques, cover, canopy cover, line intercept, monumentation, tools, permanent plots, point intercept, point frames.

380. Fletcher, S. W. 1983. **Evaluation of methods for sampling vegetation and delineating wetland transition zones in southern Louisiana**. Exp. Sta. Tech. Rep. Y-83-1. Vicksburg, MS: U.S. Army Engineers Waterways Experiment Station. 304 p.

field techniques, cover, density, community composition, community-level, shrub, herbaceous species, distance methods, wetland, vegetation sampling overview.

381. Flewelling, J. W. 1981. **Compatible estimates of basal area and basal area growth from remeasured point samples**. Forest Science. 27(1): 191-203.

permanent plots, sampling design, design, forest, tree, repeated measures analysis, field techniques, basal area, variable plots.

382. Floyd, D. A.; Anderson, J. E. 1987. **A comparison of three methods for estimating plant cover**. Journal of Ecology. 75: 221-228.

A total of 136 lines (20m long) were sampled using three methods of estimating plant cover: 1) line intercept; 2) 20 ocular estimation frames of 20x50cm; and 3) 20 point intercept frames, 50x100cm in size with 36 pins. For common shrub species, line intercept gave the highest cover values, likely because the methodology ignores small gaps in the canopy. For rare species, ocular estimation gave the highest values. For precise estimations, point intercept was the most efficient in sampling time for most species and growth forms.

field techniques, cover, canopy cover, point intercept, point frames, ocular estimation, line intercept, technique comparison.

383. Floyd, D. A.; Anderson, J. E. 1982. **A new point frame for estimating cover of vegetation**. Vegetatio. 50: 185-186.

Two methods were compared for estimating cover along eighteen 20m long transects: line intercept and point intercept measured in 20 point frames. The frame was 50x100cm, with an upper and lower portion separated by 10cm. Fishing line was strung through holes placed at 10cm intervals to make a double-sighting grid of 36 crosshairs. Cover values measured by the two methods were not significantly different, but the point frames recorded 18 forb species compared to 10 in the line intercept samples. Point interception gave higher estimates of bare ground and litter, while line intercept gave higher estimates of shrub cover, likely caused by assuming complete canopy coverage within the shrub outline for line intercept. For forbs and graminoids, the two methods gave similar results, but line intercept required about 35% longer to achieve the same precision.

point frames, cover, canopy cover, point intercept, line intercept, tools, technique comparison, field techniques, tools.

384. Fogel, M. M.; Anaya, M. G. 1981. **Climatic data needs for efficient management of arid lands**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-November 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 61-67.

In arid lands, climatic stressors such as several months of drought followed by intense erosive rains are common rather than abnormal events. The standard precipitation station is not equipped to measure the important physical properties of rainfall significant to erosion, such as intensity, raindrop size, drop size distribution, and terminal velocity of falling drops. Knowing these parameters, however, is critical to the interpretation of monitoring data.

general examples, large-scale monitoring, integrated monitoring, biological significance, environmental monitoring programs.

385. Fonteyn, P. J.; Mahall, B. E. 1981. **An experimental analysis of structure in a desert plant community**. Journal of Ecology. 69: 883-896.

community-level, community composition, desert, community structure, general examples.

386. Foody, G.; Curran, P., eds. 1994. **Environmental remote sensing from regional to global scales**. New York, NY: Wiley. 224 p.

remote sensing, large-scale monitoring.

387. Foran, B. D. 1987. **Detection of yearly cover change with Landsat MSS on pastoral landscapes in central Australia**. Remote Sensing of the Environment. 23: 333-350.

remote sensing, Landsat, MSS, cover, landscape change, landscape-level, grassland.

388. Foran, B. D.; Basin, G.; Shaw, K. A. 1986. **Range assessment and monitoring in arid lands: the use of classification and ordination in range survey**. Journal of Environmental Management. 22: 67-84.

inventory, rangeland, multivariate analysis, monitoring overviews, analysis.

389. Foran, B. D.; Pickup, G. 1984. **Relationship of aircraft radiometric measurements to bare ground on semi-desert landscapes in central Australia**. Australian Rangeland Journal. 6: 59-68.

Radiometric sensors combined with a synchronized 70mm camera mounted on a fixed-wing aircraft were used to estimate vegetation cover changes over a period of 7 weeks on 700 sites in central Australia. Vegetative cover was estimated from the photographs by projecting the image onto a gridded screen and sampling 100 points. A large rainfall event occurred the second week of the study. By the fifth

week after the rainfall, the soils were dry, similar to the first data collection, thus the changes in the radiometric data could be attributed to cover change. Cover increased from 7% to 50% in response to the precipitation. In comparing the radiometric and photographic data, the authors concluded that the cover-radiance relationship was robust and ecologically informative.

cover, desert, canopy cover, vegetation mapping, detecting change, large-scale monitoring, aerial photography, remote sensing.

390. Forthofer, R. N.; Lee, E. S. 1995. **Introduction to biostatistics: a guide to design, analysis and discovery**. New York, NY: Academic Press. 567 p.

This introductory statistics text strives to place procedures within the context of what the data represent, how the data were collected, whether the data can be used to generalize about the target population, and what problems occur when the data are incomplete (a common feature of biological data). The book assumes no prior knowledge of statistics, and little mathematical ability, although the authors do "assume the reader is not rendered unconscious by the sight of a formula." Examples are primarily biomedical, but are numerically short to keep calculations easy. The authors assume that the user will probably use computer analyses, and include MINITAB and SAS commands and printouts.

statistics overview, analysis.

391. Fortin, M. J.; Drapeau, P.; Legendre, P. 1989. **Spatial autocorrelation and sampling design in plant ecology**. Vegetatio. 83: 209-222.

sampling design, plot selection, design.

392. Foster, D. R. 1985. **Vegetation development following fire in *Picea mariana* (black spruce)--*Pleurozium* forests of south-eastern Labrador, Canada**. Journal of Ecology. 73: 517-534.

landscape-level, prescribed fire, tree, forest, succession, detecting change, community-level.

393. Foster, D. R.; Orwig, D. A.; McLachlan, J. S. 1996. **Ecological and conservation insights from reconstructive studies of temperate old-growth forests.** Trends in Ecology and Evolution. 11: 419-424.

natural variability, objectives, predicting change, community change, community-level.

394. Foster, M. S.; Harrold, C.; Hardin, D. D. 1991. **Point versus photo quadrat estimates of the cover of sessile marine organisms**. Journal of Experimental Marine Biology and Ecology. 146: 193-203.

Cover estimates derived from photo quadrats and point intercept quadrats were compared for intertidal communities. Quadrats were 30x50cm. Usually 6 photographs were taken of each plot: 3 of the overstory at 3 f-stops, and 3 additional photos of the understory, with the overstory held aside. Photographs were projected onto a 100-dot grid and the intersection of the grid with vegetation used to determine percent cover. Point intercepts were completed in the field by lowering a pointed rod at 50 random locations through a perforated plexiglas sheet suspended over the photographed quadrat. All species contacted as the rod was lowered were recorded (multiple hits on the same species were ignored). The thickness of the plexiglas ensured that rods were lowered perpendicular to the ground surface. Point quadrats consistently produced higher estimates than the photo quadrat estimates, up to 2.3 times higher. Fewer species were recorded by photo quadrats compared to point intercepts. In addition, in photo quadrats the 3 most abundant species accounted for over 90% of the cover, compared to 3 species for the point intercept. Photo quadrats thus provided a picture of the community that was structurally simpler than that of the point intercepts. The differences between the two methods were primarily due to the difficulty of moving the overstory species aside so that understory species could be photographed. Failure to identify species on the photographs and low resolution also contributed to the differences between the two methods.

field techniques, canopy cover, point frames, point intercept, photoplots, technique comparison, tools, cover, community composition, aquatic.

395. Fowler, J.; Cohen, L. 1990. **Practical statistics for field biology**. Philadelphia, PA: Open University Press. 227 p.

This is an extremely readable text on statistics, using examples from field biology and ecology throughout. The purpose is threefold: 1) provide sufficient grounding in techniques to enable understanding of the published literature; 2) present a toolbox of methods appropriate to the types of situations often encountered by field biologists; and 3) give examples and guidance for the presentation of results. Subjects covered are introductory, standard techniques (calculation of confidence limits, chi^2, correlation, regression, t-tests, ANOVAs, and a few nonparametric tests). Since biological data are often skewed, concepts of normality and transformations are covered at length.

analysis, statistics overview.

396. Fowler, N. 1990. **The ten most common statistical errors**. Bulletin of The Ecological Society of America. 71: 161-164.

The most common errors are: 1) failing to clearly explain experimental design and statistical methods of analysis; 2) using many separate statistical tests, resulting in some chance significant results, rather than the appropriate model; 3) ignoring assumptions of tests; 4) misinterpreting significance; 5) confounding effects by pooling sampling units; 6) failing to consider power; 7) incorrect use of multiple comparison tests; 8) lack of replication; 9) failing to acknowledge confounding factors; and 10) analyzing repeated measures of the same sampling unit as if they were independent.

analysis, statistics overview.

397. Fox, D. G.; Bernabo, J. C.; Hood, B. 1987. **Guidelines for measuring the physical, chemical and biological condition of wilderness ecosystems**. Gen. Tech. Rep. RM-146. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 48 p.

general examples, integrated monitoring, special sites, wilderness, global change monitoring, monitoring overviews.

398. Fox, J. E. D. 1981. **Time compaction analysis**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 377-383.

The sampling methodology to evaluate the regeneration of a widespread tree in Australia is described. Samples were distributed in strata defined by fire and cutting episodes.

general examples, tree, inventory, large-scale monitoring, community composition, seedling, sampling design, community-level, landscape-level.

399. Francis, R. E.; Kerbs, R. R.; Davey, P. R. 1983. **Technical notes -- a multipurpose inventory tool**. Journal of Range Management. 36(5): 675.

This technical note gives construction plans for a fiberglass, collapsible, graduated, multipurpose rod for use in resource inventory work. This rod can be used to estimate water depth and several vegetation and soil attributes.

field techniques, tools, inventory.

400. Francis, R. C.; VanDyne, G. M.; Williams, B. K. 1979. **An evaluation of weight estimation double sampling as a method of botanical analysis**. Journal of Environmental Management. 8: 55-72.

This paper evaluates the standing crop sampling method known as weight estimation, in which a portion of the plots are clipped, hand separated, and weighed, and the remainder are measured by ocular estimate. A review of the literature provided the following conclusions: 1) time to clip versus time to estimate ratios range from 5:1 to 10:1; 2) coefficients of predictions range from 80 to 96%; 3) estimates are within 10% of actual weight over a large range of weights; 4) workers overestimate for lower weights and underestimate for higher; 5) uniform vegetation and bunchgrasses are the life-forms most consistently estimated; 6) training improves estimates; and 7) the optimal ratio of clipped to estimated plots range from 1:4 to 1:11. The remainder of the paper compares ratio estimators (the regression relationship between clipped and estimated plots constrained through the origin) and regression estimators (unconstrained). Using simulation and actual data, the authors found that the regression estimator always produced the smaller variance ratio, up to a 10% reduction in 66% of the trials, implying that the relationship between clipped and estimated does not always pass through the origin. This result also means that sampling costs may be less when the regression estimator is used. This study also found the effectiveness of weight estimation for increasing the precision of the standing crop estimate varied by species and life form, performing best for forbs and poorly for sod-forming grasses.

field techniques, production, design, biomass, community composition, weight estimate, double sampling, precision.

401. Franklin, J. F. 1989. **Importance and justification of long-term studies in ecology**. In: Likens, G. E., ed. Long-term studies in ecology - approaches and alternatives. New York, NY: Springer-Verlag: 3-19.

The author describes the important role of long-term studies and associated data sets in validating basic ecological concepts and predictive models, most of which have been developed from short-term studies. The author first provides examples illustrating the need for long-term studies to understand certain types of ecological phenomena including: slow processes such as succession and population dynamics of long-lived organisms, rare events or episodic phenomena, processes with high variability, subtle processes, and complex phenomena. Next, the author identifies and discusses essential components in systematic long-term ecological studies, and then reviews current long-term ecological monitoring and research programs. The paper concludes with a plea to the ecological community to make a commitment to long-term studies.

monitoring examples, long-term ecological monitoring, succession, detecting change.

402. Franklin, J. 1986. **Thematic mapper analysis of coniferous forest structure and composition**. International Journal of Remote Sensing. 7(10): 1287-1301.

remote sensing, Landsat, TM, community composition, community structure, community-level, forest, coniferous forest, tree.

403. Franklin, J. F. 1981. **Wilderness for baseline ecosystem studies**. Proceedings XVII IUFRO World Congress; 1981; Japan. [Place of publication unknown]: International Union of Forest Research Organizations: 37-48.

This paper outlines the value of Wilderness and natural areas as baseline sites for ecosystem research. The author discusses the importance of studying and understanding how non-manipulated natural systems operate as a basis for developing more sustainable management prescriptions on commodity lands. The large size of Wilderness provides opportunities for research on ecosystem integrity that are unavailable in smaller preserves. Four examples of ecosystem research in Wilderness are discussed: 1) studies of relationships between terrestrial and aquatic ecosystems using entire watersheds; 2) studies of larger herbivores and predators, often encompassing complete ranges; 3) studies of vegetation mosaics, successional relationships, and disturbance histories as means of understanding the range of natural variation; and 4) monitoring of background levels of environmental pollutants. The author uses the Hoh River

Ecosystem Study to illustrate the value of Wilderness in studying relationships between geomorphic processes, terrestrial, and aquatic communities at a watershed level, and how knowledge from this research was applied to other lands. Finally, the author discusses two primary limitations of utilizing Wilderness for baseline ecosystem studies. First, all Wilderness is not free of human perturbations such as grazing, hunting, and fire control. Secondly, administrative and legislative constraints may limit the type of research and instrumentation which may be implemented within Wilderness.

special sites, monitoring examples, landscape-level, wilderness, baseline monitoring, large-scale monitoring, reference areas, pattern, landscape change, ecosystem management, succession, disturbance.

404. Franklin, J. F.; Bledsoe, C. S.; Callahan, J. T. 1990. **Contributions of the long-term ecological research program**. BioScience. 40(7): 509-523.

This paper provides an overview of the National Science Foundation's Long Term Ecological Research Program (LTER). The LTER Program was initiated in 1977 to support long-term studies in ecology focusing on five broad topics: 1) pattern and control of primary productivity; 2) dynamics of populations of organisms selected to represent trophic structure; 3) pattern and control of organic matter accumulation in surface layers and sediments; 4) patterns of inorganic inputs and movements of nutrients through soils, groundwater, and surface waters; and 5) patterns and frequency of disturbances. An office at the University of Washington in Seattle provides coordination for the long-term studies within the network of seventeen sites from Puerto Rico to Alaska. In recent years the LTER program has adopted a minimum standard installation for all studies, which greatly enhances the effectiveness of the network for monitoring long-term changes over larger spatial scales. This paper provides a good overview of the different kinds of long-term studies conducted on LTER sites and discussion of their contributions.

monitoring examples, long-term ecological monitoring, ecological monitoring programs.

405. Franklin, J. F.; DeBell, D. S. 1988. **Thirty-six years of tree population changes in an old-growth *Psuedotsuga-Tsuga* forest**. Canadian Journal of Forest Research. 18: 633-639.

long-term ecological monitoring, community-level, tree, general examples, forest, detecting change, community structure.

406. Franklin, J. F.; Forman, R. T. T. 1987. **Creating landscape patterns by forest cutting: ecological consequences and principles**. Landscape Ecology. 1: 5-18.

landscape-level, pattern, landscape change, ecosystem management.

407. Franklin, J. F.; MacMahon, J. A.; Swanson, F. J.; Sedell, J. R. 1985. **Ecosystem responses to the eruption of Mount St. Helens**. National Geographic Research. 1: 198-216.

ecological processes, landscape-level, community-level, disturbance, succession.

408. Frazier, B. E.; Hanrahan, T.; Moore, B. C. 1993. **Color aerial slide photography for detection of *Lythrum salicaria*, purple loosestrife, in wetland environments of Washington**. Proceedings of the 14th biennial workshop on color aerial photography and videography for resource monitoring; 1993 May 25-29; Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 37-47.

Aerial photographs (1:5000 and 1:12,000 scales) of sites with varying known levels of infestation of purple loosestrife were taken using standard color transparency film (Fuji Velvia 50, Kodak Ektachrome 100, and Kodachrome 64). Quadrats marked on slides were ranked from 1 to 5 for level of infestation by 46 observers, using a binocular microscope at 20x power (resulting in 1:250 and 1:600 scale). Fuji film allowed the best interpretation, followed by Ektachrome and Kodachrome. Large infestations were more easily seen, but small scattered populations were located by some observers. Screening observers with initial tests using slides of known concentrations should improve the likelihood of locating small infestations.

remote sensing, aerial photography, exotics, cover.

409. Freedman, B.; Hutchinson, T. C. 1980. **Long-term effects of smelter pollution at Sudbury, Ontario, on forest community composition**. Canadian Journal of Botany. 58: 2123-2140.

This paper takes a spatial approach in measuring the effects of a smelter, using distance from the smelter as an environmental gradient and comparing sites nearby with similar sites farther away. The point-in-time measurements of vegetation distributed over the disturbance gradient are interpreted as changes caused by the long-term operation of the smelter.

community-level, community composition, community change, succession, coniferous forest, deciduous forest, gradient analysis.

410. French, N. R.; Mitchell, J. E. 1983. **Long-term vegetation changes in permanent quadrats at the Idaho National Engineering Laboratory Site**. Forest, Wildlife and Range Exp. Sta. Bull. 36. Moscow, ID: University of Idaho. 42 p.

monitoring examples, long-term ecological monitoring, rangeland, permanent plots, protected areas.

411. Friedel, M. H. 1987. **A preliminary investigation of woody plant increase on the western Transvaal and implications for veld assessment**. Journal of The Grassland Society of Southern Africa. 4: 25-30.

community-level, landscape-level, landscape change, community change, shrub, tree, grassland, succession, disturbance, indicators.

412. Friedel, M. H. 1991. **Range condition assessment and the concept of thresholds: a viewpoint.** Journal of Range Management. 44: 422-433.

community composition, ecosystem management, detecting change, inventory, rangeland, grassland.

413. Friedel, M. H. 1990. **Some key concepts for monitoring Australia's arid and semi-arid rangelands.** Australian Rangeland Journal. 12: 21-24.

monitoring overviews, rangeland, grassland, objectives.

414. Friedel, M. H.; Bastin, G. N. 1988. **Photographic standards for estimating comparative yield in arid rangelands.** Australian Rangeland Journal. 10: 34-38.

This paper describes a modification of the conventional comparative yield method used in arid rangelands. The modification is designed to avoid problems in calibration of quadrats read by different observers. To improve yield estimates, the authors substituted a folio of photographs for the selection and assessment of reference standards and calibration of quadrats. The method is described in detail, and is recommended for use in combination with the dry-weight-rank technique for determining species composition.

photoplots, field techniques, rangeland, ocular estimation, production, dry-weight-rank.

415. Friedel, M. H.; Bastin, G. N.; Griffin, G. F. 1988. **Range assessment and monitoring in arid lands: the derivation of functional groups to simplify vegetation data.** Journal of Environmental Management. 27: 85-97.

species lists, landscape-level, community-level, monitoring overviews, functional groups, rangeland.

416. Friedel, M. H.; Chewings, V. H.; Bastin, G. N. 1988. **The use of comparative yield and dry-weight-rank techniques for monitoring arid rangeland.** Journal of Range Management. 41(5): 430-435.

Differences among observers were unacceptably large for the comparative yield method. Observers achieved fairly good consistency with the dry-weight-rank method within about 80 minutes.

field techniques, production, community-level, biomass, community composition, dry-weight-rank, observer variability.

417. Friedel, M. H.; Shaw, K. 1987. **Evaluation of methods for monitoring sparse patterned vegetation in arid rangelands. I. Herbage.** Journal of Environmental Management. 25: 297-308.

Six observers were used to compare the monitoring of rangeland herbaceous species by point sampling of aerial cover with a wheelpoint apparatus (up to 2000 points at some sites), frequency sampling in nested quadrats ($0.1m^2$, $0.25m^2$ and $1m^2$), quadrat harvesting for weight, and whole site estimation. Basal cover measurements were initially included but abandoned because the low cover values (2.4% or less) required an impractical number of samples. Data analysis was conducted in the field to ensure that an adequate sample had been collected. Frequency measures were rapid, and estimates of species composition were the most similar among observers of any of the methods tested. Differences between observers became significant at higher sample sizes, perhaps because of consistent bias in measuring the plot or misidentification of species. Cover estimation was significantly different between observers, and stabilization of the estimates never occurred at some of the sites sampled. The variance of estimates from harvested quadrats was also high; more than 10 quadrats would be required for reasonable precision at most of the sites, and the method was the most time consuming. There was good agreement among observers for whole site estimation for weight after training with clipped plots. Estimates of composition remained variable among observers, even after training. The authors concluded that none of the methods tested provided reliable results when a number of observers were used, but of those evaluated, frequency was the best option.

herbaceous species, field techniques, cover, production, community composition, rangeland, canopy cover, point intercept, frequency, nested frequency, weight estimate, observer variability, detecting change, technique comparison.

418. Friedel, M. H.; Shaw, K. 1987. **Evaluation of methods for monitoring sparse patterned vegetation in arid rangelands. II. Trees and shrubs.** Journal of Environmental Management. 25: 297-308.

Six observers were used to compare methods of measuring woody vegetation: 1) cover measured by a wheelpoint apparatus (1000 or more points) and by 2) the Bitterlich gauge; 3) density measured in long narrow quadrats (2m by the length of the site); and 4) visual estimates for the entire site. Sampling 200 points in some vegetation types provided estimates with a coefficient of variation (CV) of less than 10%, but at other sites, the CV remained above 20% even at the maximum number of points. In the single-species dominated sites, between-observer differences were not significant, but in more complex types between-observer differences became more significant as the sample size increased. For the Bitterlich method, CVs between observer's cover estimates ranged from 6.7% to 15.3%, declining as sample size increased. The method was extremely rapid. Density counts had high CVs, and a large number of quadrats would be needed in these vegetation types to give a reasonably precise estimate. Whole-site estimated densities were consistently much higher than the actual counts, and were highly variable among observers.

community-level, field techniques, cover, tree, shrub, community composition, shrub grassland, rangeland, density, canopy cover, point intercept, observer variability, ocular estimation, technique comparison, detecting change.

419. Frischknecht, N. C. 1981. **Double-frequency sampling for inventorying vegetation on salt desert shrub ranges**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 435-440.

An early approach to nested frequency plots is described. A 2x5ft frame is divided into ten 1ft² plots. Noting presence or absence in the smaller contiguous plots also measures the larger one, and provides a distribution index based on the ratio of frequency in the smaller plots compared to the larger one. Evaluation of the two plot sizes together provides additional information for biological interpretation of changes over time and comparison of sites.

field techniques, frequency, nested frequency, plot dimensions.

420. Fuhlendorf, S. D.; Smeins, F. E. 1996. **Spatial scale influence on longterm temporal patterns of a semi-arid grassland**. Landscape Ecology. 11(2): 107-113.

The influence of spatial scale (quadrat compared to site) was examined using a data set from permanent plots monitored over 45 years.

scale, landscape-level, community-level, community change, grassland, permanent plots, long-term ecological monitoring, monitoring examples.

421. Gabbert, W. D.; Schultz, B. W.; Angerer, J. P.; Oster, W. K. 1995. **Plant succession on disturbed sites in four plant associations in the northern Mojave desert**. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 183-188.

The Department of Energy has committed to reclaiming all lands disturbed by the proposed Yucca Mountain nuclear waste storage area to vegetation composition and productivity similar to predisturbance conditions. To aid the development of vegetational objectives, this study was initiated to describe characteristics of natural plant succession that has occurred on areas disturbed since 1979. To sample vegetation on 57 disturbed sites, three to six 2x20m density quadrats were randomly established at each site. To allow comparison with undisturbed vegetation, 48 areas (12 in each of the four vegetation associations) were sampled with 8 to 10 randomly located 2x50m density quadrats. The study design allowed effective comparison of vegetation on disturbed and native sites, as illustrated by graphical portrayal of species densities (mean and standard error). The sampling also provided a precise description of native vegetation that will be sufficient for establishing quantitative reclamation objectives.

landscape-level, design, field techniques, general examples, objectives, disturbance, vegetation treatments, restoration, sampling design, plot dimensions, desert, density, community comparisons, community-level.

422. Gaines, S. D.; Denny, M. W. 1993. **The largest, smallest, highest, lowest, longest, and shortest: extremes in ecology**. Ecology. 74: 1677-1692.

statistics overview, analysis.

423. Gaiser, R. N. 1951. **Random sampling within circular plots by means of polar coordinates**. Journal of Forestry. 49: 916-917.

design, plot dimensions, sampling design, field techniques, plot selection, random sampling.

424. Ganey, J. L.; Block, W. M. 1994. **A comparison of two techniques for measuring canopy closure**. Western Journal of Applied Forestry. 9(1): 21-23.

forest, canopy, canopy cover, technique comparison, crown diameter, field techniques, tree.

425. Gardiner, H. G.; Norton, B. E. 1983. **Do traditional methods provide a reliable measure of range trend?** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 618-622.

Measurement of range trend for management requires separation of treatment effects, climatic fluctuation, and intrinsic succession. Traditional biomass measures are highly susceptible to climatic influences, and may give erroneous impressions, especially over the short term. Cover data emphasizes the dominant species, and larger, older plants. Frequency data, while easy to collect, can often be difficult to interpret since small minor species can have high relative frequencies if they are well-dispersed throughout the area. The authors recommend a demographic approach of monitoring individuals within permanent plots. To compare treatments, the authors developed several simple models of survival and tested the goodness of fit of these with the observations. The simplest explanatory model was used to determine if survival rates differed between two treatments.

community-level, herbaceous species, field techniques, herbaceous species, community composition, community change, rangeland, canopy cover, cover, biomass, frequency, demographic techniques, detecting change, biological significance, technique comparison.

426. Gardner, R. H.; Milne, B. T.; Turner, M. G.; O'Neill, R. V. 1987. **Neutral models for the analysis of broad-scale landscape pattern**. Landscape Ecology. 1: 19-28.

landscape-level, pattern, analysis, large-scale monitoring, analysis.

427. Garsd, A.; Howard, W. E. 1981. **A 19-year study of microtine population fluctuations using time-series analysis**. Ecology. 62(4): 930-937.

analysis, monitoring examples, long-term ecological monitoring, time series.

428. Garton, E. O. 1984. **Cost-Efficient baseline inventories of research natural areas**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., tech. coords. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 40-45.

The author proposes a strategy for conducting cost-efficient baseline monitoring in research natural areas (RNAs). The elements of this strategy include a systematic team approach, careful definition of objectives, continuous effort to simplify, and the use of cost-efficient survey methods. The author provides two useful tables in this paper. The first is a checklist of steps for inventorying RNAs. The second provides cost-efficiency ratings of methods utilized to inventory and monitor characteristics of RNAs. The ratings range from 1 to 5, from very cost efficient, to extremely expensive.

monitoring examples, special sites, interdisciplinary design, objectives, natural areas, integrated monitoring, baseline monitoring, inventory.

429. Gauch, H. G. 1982. **Multivariate analysis in community ecology**. New York, NY: Cambridge University Press. 298 p.

This book is one of several standard texts on multivariate analysis of community data. It is probably the least mathematical of these, and thus the most accessible as an introduction. The book stresses understanding of the application of methods, rather than a mathematical understanding of the methods themselves. Examples are generally numerically simple, so the results can be easily compared to the original data set. Examples are mostly of vegetation samples, although examples from other fields are included.

analysis, multivariate analysis, statistics overview.

430. Geier-Hayes, K. 1994. **Natural regeneration in two central Idaho grand fir habitat types**. Res. Pap. INT-472. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

coniferous forest, tree, seedling, community-level, forest, general examples, succession.

431. Gerrodette, T. 1987. **A power analysis for detecting trends**. Ecology. 68: 1364-1372.

Power analysis for linear regression of trends (estimated abundance plotted against time) is described. The effects of the precision of the estimates of abundances, the magnitude of rate of change, the asymmetry between upward and downward trends, and the levels of Type I and Type II errors are explained in both mathematical and graphical form (power curves). Both linear and exponential models of change are considered. The experimental design relationship between the variability of the sample (here estimated by the coefficient of variation, CV), the number of sampling units, the desired magnitude of change that should be detected, and the Type I and II error rate is discussed. The author acknowledges that two types of variability are important: measurement error and real variability in time and space. Calculating the CV of the replicate samples estimates the measurement error. Estimating the CV associated with residual variance about the regression line incorporates real temporal variability, as well as real deviations from the model's linear or logarithmic relationship.

analysis, design, sampling design, experimental design, power, precision, detecting change, Type I and Type II errors.

432. Gertner, G. Z. 1989. **The sensitivity of measurement error in stand volume estimation**. Canadian Journal of Forest Research. 20: 800-804.

observer variability, biological significance, field techniques, DBH, tree, forest, inventory.

433. Ghent, A. W. 1993. **An exact test and normal approximation for centrifugal and centripetal patterns in line and belt transects in ecological studies**. American Midland Naturalist. 130: 338-355.

Some sampling designs utilize a belt transect, where there are N observations along the belt (say plots) with n observations of one kind (e.g., occurrence of a target species) and N-n observations of a second or all other kinds (e.g., no occurrence). If the belt transect crosses the habitat, some species or observations are more common on the edge (centrifugal) and some more common in the center (centripetal). A number-triangle exact test of these patterns is presented, along with tables for combinations of n and N (n = 2 to 8 and N = 7 to 55). Included is a normal approximation for dealing larger values of N and n.

community-level, design, sampling design, plot selection, pattern.

434. Ghent, A. W. 1972. **A graphic computation procedure for Kendall's tau suited to extensive species-density comparison**. American Midland Naturalist. 87: 459-471.

Kendall's nonparametric correlation coefficient, tau (π), can be used to compare similarities between communities in space or time. This paper describes a graphical approach for calculation of tau for extensive species lists.

community-level, analysis, detecting change, species lists, community change, community comparisons, similarity measures.

435. Ghent, A. W. 1987. **Tau as an index of similarity in community comparisons: the opposite null orientations of contingency and correlation tests**. American Midland Naturalist. 117: 221-222.

Kendall's nonparametric correlation coefficient, π (tau), can be used as an index of similarity between communities, or to compare the same site at different times. An alternate

approach is to use a contingency table chi-square method. The null hypotheses for the two methods are opposite: for tau, similarities in two compared rank orderings are attributable to chance; for a contingency table, observed differences in proportionate frequencies are attributable to chance. Thus Type I errors in tau analysis and Type II errors in contingency analysis arise from false similarities occurring by chance. Chance (false) differences cause Type II errors in tau analysis and Type I in contingency analysis. If the question of interest is community change, then a contingency approach is suitable. If the question is whether the communities have remained the same, then a tau correlation coefficient is more efficient.

community-level, analysis, detecting change, community change, similarity measures, community comparisons, Type I and Type II errors.

436. Gibbens, R. P.; Beck, R. F. 1987. **Increase in number of dominant plants and dominance classes on a grassland in the northern Chihuahuan desert**. Journal of Range Management. 40(2): 136-139.

field techniques, cover, density, community-level, permanent plots, detecting change, charting, basal area, grassland, general examples.

437. Gibbons, J. D. 1985. **Nonparametric methods for quantitative analysis**. Columbus, OH: American Science Press. 481 p.

statistics overview, analysis, nonparametric statistics.

438. Gibson, C. W. D.; Brown, V. K. 1992. **Grazing and vegetation change: deflected or modified succession?** Journal of Applied Ecology. 29: 120-131.

community-level, analysis, herbaceous species, permanent plots, multivariate analysis, community change, succession, grassland.

439. Gilbertson, D. D.; Kent, M.; Pyatt, F. B. 1985. **Practical ecology for geography and biology. Survey, mapping and data analysis**. London: Hutchinson. 320 p.

community-level, landscape-level, vegetation mapping, inventory, analysis.

440. Gilbert, N.; Wells, T. C. E. 1966. **Analysis of quadrat data**. Journal of Ecology. 54: 675-685.

A dataset of point intercept (10-point frames) collected over eight years was used to analyze patterns of vegetation along transects. Data were collected in 122 to 225 frames per transect line (varying length) at 20ft intervals, in the same spot each year. The association between two species was calculated for every species pair occurring on the transect, providing a value (c) for each species based on the size and signs of its interaction. For each point frame, these c-values were added together for all the species occurring in the plot, and a graph of the total c-values per plot by location along the transect prepared, producing a botanical profile of the transect. These profiles corresponded well to recognizable communities. Although presentation of species profiles were lumped for the eight years, the method would also be useful in examining changes in pattern and species profiles over time.

community-level, field techniques, cover, analysis, design, pattern, community composition, multivariate analysis, point intercept, point frames, similarity measures.

441. Gilbert, R. O. 1987. **Statistical methods for environmental pollution monitoring**. New York, NY: Van Nostrand Reinhold. 320 p.

Most sampling designs and statistical analyses presented in standard textbooks assume a controlled experimental situation and normally distributed data. Such conditions are rare in environmental sampling, and many standard statistical tests (t-tests, ANOVAs) are inappropriate for environmental data. Although this book is specifically addressing pollution monitoring and research, the concepts and designs are applicable to all kinds of environmental sampling, including vegetation. About half of the book discusses sampling designs, such as two-stage, composite, three-stage, double, and systematic. The remaining part of the book focuses on calculation of variance and confidence limits for skewed distributions (which are the norm rather than the exception in environmental data) and detecting and estimating trends. The book is written for nonstatisticians who have had one or two introductory courses. The mathematics are not daunting, and examples are abundant. Exercises and answers are included in each chapter.

analysis, trend analysis, statistics overview.

442. Gillen, R. L.; Smith, E. L. 1986. **Evaluation of the dry-weight-rank method for determining species composition in tallgrass prairie**. Journal of Range Management. 39: 283-285.

Measures of species composition include density, frequency, cover, and dry weight. The last is considered the best indicator of species importance within a community, but is very time-consuming. The dry-weight-rank method (DWR) is a less time consuming method of measuring composition than the standard approach of clipping, separating the material by species, and drying. The three most abundant species on a plot are ranked 1, 2, and 3. A series of multipliers developed from the relationship between ranked and clipped plots are used to calculate the percent composition, but the use of standard multipliers would eliminate this time requirement. Standard multipliers for ranks 1, 2, and 3 (70%, 21%, and 9%) were used in this study of the tall-grass prairie and were found to perform adequately except on one site with a single dominant species. Standard deviations of the DWR method were higher than samples of clipped plots for a given sample size, but since the former only required 1.6 minutes per plot compared to 28 minutes for clipped plots, sample size could be much larger for DWR. In this study, the 50 DWR plots provided more precise estimates than 20 clipped plots in over 96% of the trials. Accuracy of the DWR method was reduced by

observer variability, demonstrating the need for careful training.

field techniques, community-level, weight estimate, technique comparison, community composition, dry-weight-rank, production, observer variability.

443. Gillison, A. N.; K. R. W. Brewer. 1985. **The use of gradient directed transects of gradsects in natural resource survey**. Journal of Environmental Management. 20: 103-127.

baseline monitoring, inventory, design, plot selection, sampling design.

444. Gimingham, C. H. 1951. **The use of life form and growth form in the analysis of community structure as illustrated by a comparison of two dune communities**. Journal of Ecology. 39: 396-406.

landscape-level, community-level, functional groups, indicators.

445. Gison, D. J.; Sestedt, T. R.; Briggs, J. M. 1993. **Management practices in tallgrass prairie: large and small-scale experimental effects on species composition.** Journal of Applied Ecology. 30(2): 247-255.

scale, landscape-level, community-level, herbaceous species, grassland, design.

446. Given, D. R. 1989. **Monitoring of threatened plants**. In: Craig, B., ed. Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on protected natural areas; 1988 May; Dunedin. Wellington: Department of Conservation: 192-198.

Monitoring of rare plants is essential to detect changes in abundance, determine the cause of change, and to recommend appropriate management. Three aspects of monitoring include: 1) inventory, which utilizes historical records and notes as well as more recent repeated inventories to monitor coarse-scale changes; 2) surveys and repeated field assessments which are qualitative in nature, supplemented by photographs and photopoints, and done by amateurs (a tested four-page data form is available on request); and 3) experimental monitoring, which is intensive study often utilizing demographic or ecophysiological methods. Recognizing that even the first level of monitoring cannot be done for all plants, the author recommends the following priorities for monitoring: 1) species which are approaching critical rarity, for which conservation costs currently are low, but will rise as options decrease from human development; 2) species which are umbrella or keystone, those on which a number of other species depend; 3) known genetic variants of widespread species; 4) species with a particular cultural or traditional use.

special sites, rare species, natural areas, indicators, demographic techniques, monitoring examples, photopoints, monitoring overviews.

447. Glantz, S. A. 1997. **Primer of biostatistics. 4th ed**. New York, NY: McGraw-Hill. 473 p.

statistics overview, analysis.

448. Glatzle, A.; Mechel, A.; Vaz Lourenco, M. E. 1993. **Botanical components of annual Mediterranean grassland as determined by point-intercept and clipping methods**. Journal of Range Management. 46: 271-274.

Three methods of determining botanical composition (grass, legume, and forb groups) were compared: 1) clipping; 2) frequency by species measured by interception of the canopy (point intercepts); and 3) multiple point interception of the sward. The latter records all hits with the vegetation as a pin descends vertically toward the ground, whereas the second only records an occurrence for a particular species once for each pin. Measurements of 30 clipped plots ($1m^2$) and 200 points were taken monthly between January and May in a Portuguese pasture. Point intercept methods underestimated forbs and overestimated legumes compared to clipped composition, but provided good estimates of grasses. When all vegetative components were considered together, both frequency and multiple interception had high correlation with composition measured by clipping ($r=0.93$ and $r=0.92$ respectively). The two point methods were also highly correlated with each other ($r=0.99$) and were never significantly different, explained perhaps by the consistently short sward height (<8cm) and the rarity of multiple interceptions. Using the relatively rapid frequency of interception method may have applications to double sampling approaches for measuring composition, preferable to the standard approach of ocular estimation.

field techniques, production, community-level, cover, canopy cover, point intercept, biomass, frequency, performance, ocular estimation, community composition, canopy volume, double sampling, technique comparison.

449. Glendening, G. E. 1952. **Some quantitative data on the increase of mesquite and cactus on a desert range in southern Arizona**. Ecology. 33: 319-328.

shrub, herbaceous species, desert, detecting change, succession.

450. Glenn, S. M.; Collins, S. L.; Gibson, D. J. 1992. **Disturbances in tallgrass prairie: local and regional effects on community heterogeneity**. Landscape Ecology. 7: 243-251.

The hypothesis tested was that regional (between site) heterogeneity would be greater in grazed versus ungrazed sites and lower on burned versus unburned sites in tallgrass prairie vegetation. Twenty-eight sites (burned, burned and grazed, grazed, undisturbed) were sampled with 10 permanent $2m^2$ circular plots in which cover was visually estimated by class. Regional heterogeneity was measured by the percent dissimilarity between pairs of sites, and paired t-tests used to determine if there were significant differences in regional heterogeneity between the four treatments. Local heterogeneity was calculated using the percent dissimilarity

between the ten plots at each site. Undisturbed sites were the most heterogenous at the local scale, but least heterogenous at the regional scale. Grazed and grazed and burned sites were generally the least heterogenous at local scales.

landscape-level, community-level, disturbance, pattern, prescribed fire, scale, community composition, community structure, cover, predicting change, grassland, canopy cover, ocular estimation, cover classes, permanent plots, similarity measures, field techniques, analysis.

451. Gloaguen, J. C. 1990. **Post-burn succession on Brittany heathlands**. Journal of Vegetation Science. 1: 147-152.

wetland, shrubland, prescribed fire, landscape-level, community-level, succession, detecting change, design, analysis.

452. Gnanadesiken, R. 1977. **Methods for statistical data analysis of multivariate observations**. New York, NY: Wiley. 311 p.

multivariate analysis, analysis, statistics overview.

453. Goebel, C. J.; DeBano, L. F.; Lloyd, R. D. 1958. **A new method of determining forage cover and production on desert shrub vegetation**. Journal of Range Management. 11: 244-246.

Plots $5ft^2$ were sampled with a frame supported on telescoping legs. An internal moveable frame 1x5ft was subdivided into units each representing 0.25% of the total ground cover of the plot. Cover was based on the number of these smaller units occupied by the vegetation. Observer differences remained significant for species with irregular or poorly defined outlines.

field techniques, cover, tools, herbaceous species, production, canopy cover, ocular estimation, observer variability, desert, shrub.

454. Goff, F. G.; Dawson, G. A.; Rochow, J. J. 1982. **Site examination for threatened and endangered plant species**. Journal of Environmental Management. 6: 307-316.

inventory, rare species.

455. Goldsmith, F. B. 1983. **Evaluating nature**. In: Warren, A.; Goldsmith, F. B., eds. **Conservation in perspective**. New York, NY: John Wiley & Sons: 223-246.

objectives, special sites.

456. Goldsmith, F. B., ed. 1991. **Monitoring for conservation and ecology**. London: Chapman and Hall. 275 p.

monitoring overviews, general book on monitoring.

457. Goldsmith, F. B. 1991. **Vegetation monitoring**. In: Goldsmith, F. B., ed. **Monitoring for conservation and ecology**. London: Chapman and Hall: 77-86.

This chapter provides an overview of and introduction to vegetation monitoring. Topics include location and approaches to sampling units, measures of species performance and abundance, and mapping schemes. The chapter provides little information on specific techniques, but does provide a good introductory overview.

general book on monitoring, community composition, vegetation mapping, field techniques, density, cover, frequency, sampling design, vegetation sampling overview.

458. Goldstein, R. 1989. **Power and sample size via MS/PC-DOS computers**. American Statistician. 43: 253-260.

Reviews 13 computer programs for their ability to analyze power and calculate sample size.

design, analysis, power, tools, sample size, sampling design.

459. Golluscio, R. A.; Sala, O. E. 1993. **Plant functional types and ecological strategies in Patagonian forbs**. Journal of Vegetation Science. 4: 839-846.

landscape-level, functional groups.

460. Good, R. E.; Good, N. F. 1971. **Vegetation of a Minnesota prairie and a comparison of methods**. American Midland Naturalist. 85: 228-231.

Point-center quarter density estimates from 24 points in eight stands of a tall-grass prairie were compared to five 50x50cm plots in which plants were clipped and stems counted. Each stand was sampled twice. The point-center quarter method gave highly variable estimates in comparison to the quadrat estimates, both over and underestimates. Repeatability of the point-center quarter method (comparison between the two samples), however, was good. Density estimates for most stands produced by the quadrat hand counts was 2400±200 stems/m^2. The point-center quarter method gave counts in the range of 1425-3775 stems/m^2.

field techniques, herbaceous species, point-center methods, density, technique comparison, grassland.

461. Goodall, D. W. 1953. **Point-quadrat methods for the analysis of vegetation**. Australian Journal of Botany. 1: 457-461.

The centers of tussock grasses are problematic for the measure of cover repetition (the number of contacts made as a pin is lowered through the vegetation) because counts become unreliable as contacts exceed about 20. For some species, a negative binomial distribution was found to describe the distribution of the number of contacts per point. Using the curve suggested by measured contacts up to 15 per point, a negative binomial distribution of best fit was developed for a particular tussock grass, *Poa cespitosa.* Based on this distribution, the mean number of contacts in the unmeasurable area is 27.3.

field techniques, grassland, herbaceous species, cover, meadow, canopy cover, point frames, point intercept.

462. Goodall, D. W. 1952. **Some considerations in the use of point quadrats for the analysis of methods**. Australian Journal of Scientific Research. 5: 1-41.

Measurement of cover by point intercept was evaluated in alpine grassland vegetation. Pin diameter was found to strongly affect cover estimates, with cover measured by crosshairs on average 66% of that measured by pins 4.75mm in diameter. Point diameter was especially important in measuring composition, since small-leaved species are overestimated above their true cover and large-leaved species underestimated. Comparisons between observers showed cover measurement by optical points was robust to different observers. Points distributed in frames of 10 required 2 to 4 times the number of points to obtain the same precision compared to points distributed randomly. A restricted random sampling design is recommended, in which a point (or several) is located at random within each cell of a regular grid pattern. This allows for an evaluation of pattern, and in some cases increased precision. For measuring changes in cover with point intercept, using repeat measurements of the same point was much more effective than using a random sample each time the area was sampled. To avoid problems of correlation with successive measurements, the suggested approach was to remeasure the points from the previous measurement, and establish a new set to be remeasured at the next measurement (point 1 at the first occasion, points 1 and 2 at the second, points 2 and 3 at the third, etc.). Similar findings and recommendations were given for cover repetition (the number of times a species is intercepted as the point is lowered- a means of measuring multi-level canopies) and "percentage of sward" (percent cover x cover repetition).

cover, field techniques, design, community composition, cover, alpine, grassland, canopy cover, point frames, point intercept, observer variability, random sampling, systematic sampling, sampling design, canopy volume, community-level.

463. Goodchild, M. F.; Parks, B. O.; Steyaert, L. T., eds. 1993. **Environmental modeling with GIS**. London: Oxford. 488 p.

landscape-level, GIS, ecological models, pattern, scale.

464. Gotfryd, A.; Hansell, I. C. 1985. **The impact of observer bias on multivariate analysis of vegetation structure**. Oikos. 45: 223-234.

observer variability, analysis, multivariate analysis, community-level, community structure, community composition.

465. Gove, J. H.; Banapati, P. P.; Taillie, C. 1996. **Diversity measurement and comparison with examples**. In: Szaro, R. C.; Johnson, D. W., eds. Biodiversity in managed landscapes. New York, NY: Oxford University Press: 157-175.

This chapter provides an overview of diversity measures including average species rarity, examples of diversity indices, and diversity profiles, including intrinsic diversity profiles (Patil and Taillie 1982). The last is illustrated in a study of pre- and post-logging treatments on two watersheds in a northern hardwood forest. One watershed was treated with strip cuts, the other with a clearcut. Because diversity estimates were based on sampling, a jackknife procedure which calculated diversity values based on resampling of the data set with one missing observation was used to develop the diversity profile for each community. Two types of comparisons were made. The same treatment area was compared over time (precut, 1 year postcut, and 10 years postcut) and the two treatment areas were compared for the same year.

landscape-level, community-level, biodiversity, community composition, diversity indices, species diversity, jackknife, randomization tests, analysis, community comparisons, detecting change.

466. Gove, J. H.; Martin, C. W.; Patil, G. P.; Solomon, D. S.; Hornbeck, J. W. 1992. **Plant species diversity on even-aged harvests at the Hubbard Brook Experimental Forest: 10-year results**. Canadian Journal of Forest Research. 22(11): 1800-1806.

landscape-level, community-level, biodiversity, species diversity, community change, community composition, detecting change, long-term ecological monitoring, general examples.

467. Goward, S. N.; Waring, R. H.; Dye, D. G.; Yang, J. 1994. **Ecological remote sensing at OTTER: satellite macroscale observations**. Ecological Applications. 4: 322-343.

This paper reports on a portion of the Oregon Transect Ecosystems Research (OTTER) study, aimed at evaluating the use of coarse, global-scale satellite imagery in characterizing primary production of forested ecosystems. Field measurements included incident photosynthetically active radiation (PAR), canopy interception of PAR, air temperature, vapor pressure deficit, and drought related to soil moisture. Reasonable fit between ground and satellite data indicates that this may be a useful technique for macroscale environmental monitoring.

monitoring examples, remote sensing, Landsat, TM, MSS, large-scale monitoring, production.

468. Graetz, R. D.; Gentle, M. R.; Pech, R. P.; O'Callaghan, J. F.; Drewien, G. 1983. **The application of Landsat image data to rangeland assessment and monitoring: an example from south Australia**. Australian Rangeland Journal. 5: 63-73.

remote sensing, rangeland, inventory, detecting change, landscape change, landscape-level, community change, community-level.

469. Graetz, R. D.; Gentle, M. R.; Pech, R. P.; O'Callaghan, J. F. 1986. **The application of Landsat image data to rangeland assessment and monitoring: the development and demonstration of a land image-based resource**

information system. Journal of Arid Environments. 10: 53-80.

remote sensing, Landsat, vegetation mapping, community change, large-scale monitoring, rangeland, community-level, monitoring examples.

470. Graetz, R. D.; Pech, R. P.; Davis, A. W. 1988. **The assessment and monitoring of sparsely vegetated rangelands using calibrated Landsat data**. International Journal of Remote Sensing. 9: 1201-1222.

Landsat data were compared to measured vegetation cover on 58 sites, each 550x550m (the size of a 3x3 pixel block of image data). Cover was measured in the field by a wheel point apparatus, with 2000 cover points measured in a regular grid at each site. Calibration of the Landsat signal with actual vegetation cover was problematic because of the small cover values of the vegetation (<10%) and the overlap in the Landsat signal for lichen cover, litter, perennial shrubs, and herbs. Soil reflectance measured by the MSS5 waveband, however, was readily separable from that of the four vegetative components, thus these components were lumped into a single variable, COVER, which was compared to bare ground. The field measures of COVER were used to calibrate the MSS5 signal. The calibrated MSS5 data were used to assess changes in cover over four years through a drought period. The changes measured by Landsat data could be understood ecologically and interpreted in a management context. Errors of estimation, although significant, were less than measured changes, and so did not obscure interpretation.

pattern, landscape change, regional planning, cover, rangeland, canopy cover, point intercept, Landsat, MSS, remote sensing, large-scale monitoring, monitoring examples, landscape-level.

471. Graham, L. A. 1993. **Airborne video for near-real-time vegetation mapping**. Journal of Forestry. 91(8): 28-32.

This paper describes how the Arizona GAP Analysis project utilized airborne GPS/video systems for generating a statewide vegetation map. In this method aerial video images are integrated with geographic position information. Photography and computer system specifications, data acquisition, interpretation, and ground-truthing procedures are explained. Documentation of the video imagery appearance of vegetation parameters at multiple scales was organized into photo-interpretation keys. These keys will be valuable in subsequent mapping and monitoring efforts.

landscape-level, community-level, general examples, vegetation mapping, aerial photography, remote sensing, GIS, video, large-scale monitoring.

472. Graham, R. L.; Hunsaker, C. T.; O'Neil, R. V.; Jackson, B. L. 1991. **Ecological risk assessment at the regional scale**. Ecological Applications. 1: 196-206.

objectives, landscape-level.

473. Grassle, J. F.; Patil, G. P.; Smith, W. K.; Taillie, C., eds. 1979. **Ecological diversity in theory and practice**. Patil, G. P., ed. Statistical ecology series, volume 6. Burtonsville, MD: International Cooperative Publishing House. 352 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "An overview of diversity," "A comparative approach to species diversity," "Some basic concepts of ecological equitability," "Species abundance, diversity and environmental predictability," "Application of the generalized jackknife to Shannon's measure of information as a measure of species diversity," "Comparing and contrasting diversity measures in censused and sampled communities," "Estimates of species diversity from multiple samples," and "Measures of diversity with unbiased estimates."

community-level, biodiversity, species diversity, similarity measures, analysis, diversity indices.

474. Graves, B. M.; Dittberner, P. L. 1986. **Variables for monitoring aquatic and terrestrial environments**. Biol. Rep. 86(5). Washington, DC: U.S. Department of Interior, Fish and Wildlife Service. 55 p.

objectives, field techniques, vegetation sampling overview, monitoring overviews.

475. Gray, J. S.; Jensen, K. 1993. **Feedback monitoring: a new way of protecting the environment**. Trends In Ecology and Evolution. 8: 267-268.

The authors describe the monitoring system developed for a large construction project. The unique features are predictions in the Environmental Impact Assessment developed by the company are quantified, unacceptable limits identified, and a statistically valid monitoring program developed. When limits are reached or exceeded, the activity is shut down. The feedback loop (the limits and the response to exceeded limits) was specified before construction began and agreed to by all parties.

monitoring and management, objectives, adaptive management, feedback loops.

476. Green, R. H. 1993. **Application of repeated measures designs in environmental impact and monitoring studies**. Australian Journal of Ecology. 18: 81-98.

analysis, repeated measures analysis, sampling design, multivariate analysis.

477. Green, R. H. 1980. **Multivariate approaches in ecology: the assessment of ecological similarity**. Annual Review of Ecology and Systematics. 11: 1-14.

Measuring similarity (similarity coefficients) or dissimilarity (distance measures) among samples or groups of samples based on the species that occur in each sample (and sometimes their abundances), is the critical first step in testing differences in community structure by multivariate methods, such as changes occurring over time. Here the

literature concerning distance and similarity measures, including earlier reviews, is cited and reviewed (over 130 references are included). Use of similarity and distance measures are preferable to diversity indices for comparing community data sets because more of the original information on species composition is retained. While the primary use of multivariate methods is descriptive, caution must be exercised in using formal multivariate tests because they are so powerful significant results are likely. Several suggestions for testing the null hypothesis (community structure or differences lacking) are presented. Computer packages and the visual display of results is also discussed.
analysis, community-level, detecting change, community composition, diversity indices, similarity measures, multivariate analysis.

478. Green, R. H. 1989. **Power analysis and practical strategies for environmental monitoring**. Environmental Research. 50: 195-205.
design, power, detecting change, sampling design, experimental design, sample size.

479. Green, R. H. 1979. **Sampling design and statistical methods for environmental biologists**. New York, NY: John Wiley & Sons. 257 p.
This is a standard and widely cited book on the design of studies to detect environmental impact. It introduces the BACI concept and describes other designs to detect change.
analysis, design, Type I and Type II errors, precision, power, sampling design, detecting change, BACI.

480. Green, R. H. 1984. **Statistical and non-statistical considerations for environmental monitoring studies**. Environmental Monitoring and Assessment. 4: 293-301.
statistical interpretation, design, analysis, monitoring and management, Type I and Type II errors, power, precision, detecting change.

481. Green, R. H.; Young, R. C. 1993. **Sampling to detect rare species**. Ecological Applications. 3(2): 351-356.
rare species, sampling design.

482. Greene, S. E. 1984. **Botanical baseline monitoring in research natural areas in Oregon and Washington**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., tech. coords. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 6-10.
Research Natural Areas (RNAs) in Oregon and Washington are being utilized to obtain baseline data to: 1) test ecological hypotheses; 2) judge the effects of management activities on similar ecosystems; 3) understand basic ecosystem processes; and 4) provide data on flora and fauna. The author describes four types of botanical baseline monitoring conducted in RNAs: successional plots, floristic surveys, ecological processes, and classification plots. Permanent plots have been established to examine growth and yield of stands and to monitor mortality. Two permanent plot methodologies are described: reference stands and circular plots. A total of 33 (1 to 2 hectares) reference stands and 250 circular plots (1000m^2) were established in Oregon and Washington RNAs as of March 1984. Floristic surveys have been completed for 14 RNAs. These surveys involved visiting each RNA several times during the growing season to capture as much of the floristic diversity as possible. Observations on habitat were also recorded for each species. Voucher specimens were collected and placed in recognized state herbaria.
special sites, monitoring examples, baseline monitoring, natural areas, permanent plots, long-term ecological monitoring, reference areas, specimen curation, inventory.

483. Greenland, D. 1986. **Standardized meteorological measurements for long-term ecological research sites**. Bulletin of The Ecological Society of America. 67: 275-277.
integrated monitoring, long-term ecological monitoring.

484. Greenland, S. 1988. **On sample-size and power calcuations for studies using confidence intervals**. American Journal of Epidemiology. 128: 231-237.
analysis, confidence intervals, precision, power.

485. Gregorire, T. G.; Scott, C. T. **Sampling at the stand boundary: a comparison of statistical performance among eight methods**. In: Burkhart, H. E., ed. Proceedings from the World Congress of International Union of Forestry Research Organizations. Blacksburg, VA: Virginia Polytechnic Institute and State University: 78-85.
sampling design, design, plot selection.

486. Greig-Smith, P. 1983. **Quantitative plant ecology. 3rd ed**. Berkeley, CA: University of California Press. 347 p.
This book is one of several standard texts on multivariate analysis of community data. It is specific to vegetation, and includes sections on sampling vegetation (cover, frequency, density). Analyses described include pattern analysis, species association, correlation with environmental factors, classification and description of communities, and ordination. Most descriptions of the techniques rely on text, figures, and examples rather than mathematics.
analysis, community-level, vegetation sampling overview, community composition, community structure, community classification, multivariate analysis, plant associations, field techniques, cover, density, frequency.

487. Grelen, H. E. 1959. **The basal area method for measuring ground cover**. In: Techniques and methods of measuring understory vegetation. Tifton, GA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 45-47.
This article describes charting and list methods for estimating cover, two methods that were widely used in the 1960s. Charting or mapping of plants within plots can be

done with a pantograph, a device that maps boundaries of plants within a quadrat onto a datasheet in the field, or by photographic methods. A list count can use ocular estimates of cover, or a measure of the area of individual plants using one of several tools that estimate diameter in one or more planes. For both methods, plants that are odd-shaped, bunchgrasses with hollow centers and plants with slender single stems are problematic.

field techniques, charting, community composition, cover, ocular estimation, basal area, canopy cover.

488. Griffen, G. F. 1989. **An enhanced wheel-point method for assessing cover, structure and heterogeneity in plant communities**. Journal of Range Management. 42: 79-81.

field techniques, cover, tools, point intercept, community composition, community-level.

489. Grosenbaugh, L. R. 1957. **Point sampling compared with plot-sampling in southeast Texas**. Forestry Science. 3: 2-14.

sampling design, design, field techniques, density, variable plots.

490. Gross, M. F.; Hardisky, M. A.; Klemas, V. 1989. **Applications to coastal wetland vegetation**. In Asrar, G., ed. Theory and applications of optical remote sensing. New York, NY: John Wiley and Sons: 474-490.

Remotely sensed boundaries of coastal wetlands are most accurate with color infrared aerial photography. The relatively large pixel size of Landsat data (4800m^2) and Thematic Mapper Data (900m^2) reduces their applicability for mapping boundaries, especially of small areas, but both have been used for vegetation classification. Remote sensors can also be used to measure wetland characteristics such as biomass.

remote sensing, Landsat, TM, wetland, aerial photography.

491. Gross, M. F.; Klemas, V.; Levasseur, J. E. 1988. **Remote sensing of biomass of salt marsh vegetation in France**. International Journal of Remote Sensing. 9: 397-408.

aerial photography, Landsat, remote sensing, wetland, community-level, landscape-level, biomass, production.

492. Gruell, G. E. 1983. **Fire and vegetative trends in the Northern Rockies: interpretations from 1871-1982 photographs**. Gen. Tech. Rep. INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 117 p.

community-level, long-term ecological monitoring, monitoring examples, photopoints, detecting change, succession, disturbance, forest, grassland, field techniques.

493. Gruell, G. E.; Schmidt, W. D.; Arno, S. F.; Reich, W. J. 1982. **Seventy years of vegetative change in a managed ponderosa pine forest in western Montana-- implications for resource management**. Gen. Tech. Rep. INT-130. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 42 p.

long-term ecological monitoring, field techniques, community-level, community change, general examples, succession, photopoints, detecting change, forest.

494. Guarnaccia Jr., D. 1961. **A method of establishment and analysis of permanent growth plots**. Bozeman, MT: Montana State University. 66 p. Thesis.

field techniques, design, production, permanent plots, forest, performance.

495. Gunasekaran, M. 1992. **Re-analysis of the vegetation of Bee Branch Gorge Research Natural Area, a hemlock-beech community on the Warrior River Basin of Alabama**. Castanea. 57: 34-45.

Using an earlier study as a baseline, the vegetation of this natural area was reassessed to determine if the hemlock population, near the southern limit for the species, was decreasing. The natural area is only 130 to 250m wide, and 2.1km long. Perpendicular transects spaced 150m apart were tiered from a baseline running the length of the natural area. On each transect, sampling points were located at 10m intervals. At each sampling point, trees >4cm diameter (DBH) were sampled using the random pairs method. Smaller trees and shrubs were counted in 5x5m quadrats and seedlings and herbaceous species were counted in 1.0x0.5m quadrats. Cover, litter, soil, etc., were estimated to a cover class within the smallest plot. Data were compared to the earlier data by using correlation analysis of relative dominance, relative density, relative frequency, and importance.

special sites, field techniques, natural areas, community composition, deciduous forest, coniferous forest, distance methods, plotless methods, random pairs, seedling, shrub, tree, baseline monitoring, long-term ecological monitoring, general examples.

496. Gurevitch, J.; Chester, S. T. 1986. **Analysis of repeated measures experiments**. Ecology. 67: 251-255.

Experiments in which measurements are taken on the same individual (or plot) over time are termed "repeated measures experiments." These data are often correlated, and it is this lack of independence among measures that necessitates multivariate analysis. Use of univariate analyses, such as ANOVA, are preferred (more power, simpler calculations, and easier interpretation), but are incorrectly applied to most repeated measures experiments. An exception is when the differences between all pairs of measurements within units have homogeneous variances. For other situations, univariate analyses may be used if each set of measurements is reduced to a single weighted value. The authors describe this technique.

analysis, multivariate analysis, experimental design, permanent plots, ANOVA, repeated measures analysis.

497. Guthery, F. S. 1987. **Guidelines for preparing and reviewing manuscripts based on field experiments with unreplicated treatments**. Wildlife Society Bulletin. 15: 306.
design, pseudoreplication, replication, experimental design.

498. Haberman, S. J. 1988. **A warning on the use of chi-squared statistics with frequency tables with small expected cell counts**. Journal of The American Statistical Association. 83: 555-560.
analysis, nonparametric statistics.

499. Hacker, R. B. 1984. **Vegetation dynamics in a grazed mulga shrubland community. II. The ground storey**. Australian Journal of Botany. 32: 251-261.
herbaceous species, shrubland, rangeland, community-level, community change, general examples.

500. Hackett, R. L.; Meyer, M. P.; Miller, N. L. 1983. **35mm aerial photography for analyzing forest land use change**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 70-74.

A monitoring system is described that combines photo interpretation of permanent plots with field data. Plots are first screened from photos (1:5300 scale) to determine if there has been any large-scale change (blowdown, fire, logging). Disturbed plots are ground surveyed. A key drawback to the approach was that recent photos were often unavailable. Cost for flights contracted specifically for taking photos of plots ($23/plot) was compared to resurveying plots by field crews ($275/plot).
landscape-level, monitoring examples, aerial photography, remote sensing, large-scale monitoring, forest, canopy cover, disturbance.

501. Hagglund, B. 1983. **The new national forest survey**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 298-303.

Early forest use required surveys that estimated production values (volume and diameter) but new, diverse uses require a survey system that meets a number of objectives. The new system monitors change and trends through a network of permanent and temporary plots. Information includes site potential, human influences, regeneration, stump surveys, and soil variables. Trees are bored for age increment on temporary plots, but not on permanent ones due to the risk of disease. Permanent plots are designed to maximize the measurement of change while temporary plots are designed to efficiently estimate production variables. Plots are clustered into tracts. Each tract requires a field day to complete. Plans were to establish 1800 tracts of temporary and permanent plots over 5 years.
landscape-level, permanent plots, inventory, forest, community change, landscape change, tree-ring analysis, large-scale monitoring, monitoring examples, integrated monitoring.

502. Hairston, N. G. 1989. **Ecological experiments: purpose, design and execution**. Cambridge, England: Cambridge University Press. 370 p.

This book provides an excellent introduction to designing field experiments in ecology. The book is structured with an introductory section of three chapters, five chapters that focus on particular systems (forests, arid lands, marine, terrestrial successional, and freshwater) and a final synthesis chapter. Throughout the book, many examples from published literature are used to illustrate good, effective design and poor, inconclusive design. Those involved in designing monitoring studies or research projects intended to show causes of observed effects will especially benefit from chapter 2, "Minimal requirements of experimental design in ecology." In this chapter, basic design elements such as controls and replication are described and their importance illustrated, common approaches such as blocks and stratification explained, and common pitfalls such as pseudoreplication and investigator impacts discussed. Each chapter on ecosystem types provides good overviews of basic ecological process specific to the type, and a large number of examples to both stimulate thinking and help avoid repeating mistakes.
design, analysis, detecting change, experimental design, replication, sampling design.

503. Hajdn, L. J. 1981. **Graphical comparison of resemblance measures in phytosociology**. Vegetatio. 48: 47-59.
analysis, community composition, community-level, community change, multivariate analysis, similarity measures.

504. Hall, E. A.; Specht, R. L.; Eardley, C. M. 1964. **Regeneration of the vegetation on Koonamore Vegetation Reserve, 1926-1962**. Australian Journal of Botany. 12: 205-264.
long-term ecological monitoring, community-level, community change, general examples.

505. Hall, F. G.; Botkin, D. B.; Strebel, D. E.; Woods, K. D.; Goetz, S. J. 1991. **Large-scale patterns of forest succession as determined by remote sensing**. Ecology. 72(2): 628-640.
remote sensing, Landsat, pattern, landscape-level, community-level, succession, landscape change, forest, tree, community change.

506. Hall, G. F.; Strebel, D. E.; Sellers, P. J. 1988. **Linking knowledge among spatial scales: vegetation, atmosphere, climate, and remote sensing**. Landscape Ecology. 2: 3-22.

integrated monitoring, global change monitoring, large-scale monitoring, landscape-level, pattern, remote sensing.

507. Hall, J. B.; Okali, D. U. U. 1978. **Observer bias in a floristic survey of complex tropical vegetation**. Journal of Ecology. 66: 241-249.

Bias among observers can arise in recording of species occurrence. In this study, 50 randomly selected 25x25m plots were sampled in a Nigerian tropical forest. All vascular plant species occurring in the plot were listed, and woody stems 10cm or more in diameter (DBH) enumerated. Fifteen of these plots were sampled under the direct supervision of the project leader and 35 were sampled by a field crew. The two groups were treated as two samples and tested for significance of differences between the means. Structural tree data did not differ between the two samples. The mean number of species in life-form classes differed significantly in 10 of the 16 classes, with the field crew consistently detecting fewer species. Differences between observers affected the first component of a principle component analysis. The bias also obscured a real seasonal species richness gradient.

analysis, field techniques, forest, tree, herbaceous species, species diversity, species richness, species lists, observer variability, multivariate analysis.

508. Hall, O. F. 1959. **The contribution of remeasured sample plots to the precision of growth estimates**. Journal of Forestry. 57: 801-811.

repeated measures analysis, permanent plots, tree, forest, field techniques, production, analysis, precision.

509. Halvorson, G. H. 1984. **Long-term monitoring of small vertebrates: a review with suggestions**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., eds. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 11-25.

Four essential elements of a monitoring program are identified: 1) data should be long-term to encompass variability; 2) design must be statistically valid and sensitive to trends; 3) implementation must be cost-effective; and 4) the data must be ecologically appropriate.

monitoring overviews.

510. Halvorson, W. L.; Veirs Jr, S. D.; Clark, R. A.; Borgais, D. D. 1988. **Terrestrial vegetation monitoring handbook**. Ventura, CA: U.S. Department of Interior, National Park Service, Channel Islands National Park. 11 p.

This is one in a series of handbooks describing methods to monitor biotic features of Channel Islands National Park. Presented is a two-tiered monitoring scheme for detecting changes in vegetation over time. Periodic vegetation mapping is conducted utilizing color infra-red aerial photo transparencies at a scale of 1:12,000. The second component of monitoring is the establishment of permanent transects. A total of 54 transects was established in 12 representative plant community types on 3 islands within the Park. Species and height are recorded at 100 pre-determined points along each 30m transect. These data are utilized to quantify species composition, frequency of occurrence, height, and cover. The authors discuss how field sampling is conducted, including timeframes, personnel, and equipment requirements. Data management and analysis is also described in detail. All data are entered into a vegetation analysis program called TRANSECT (developed by the National Park Service). The handbook also includes a series of appendices providing detailed maps showing transect locations, field data sheets, samples of TRANSECT data analysis outputs, plant species lists, and a description of the TRANSECT computer program.

field techniques, cover, permanent plots, aerial photography, remote sensing, long-term ecological monitoring, national parks, ecological monitoring programs, point intercept, canopy cover, heights, community composition, frequency, species lists, special sites, monitoring examples, community-level.

511. Hand, D. J.; Taylor, C. C. 1987. **Multivariate analysis of variance and repeated measures**. London: Chapman and Hall. 262 p.

Multivariate analysis of variance is appropriate for designs in which more than one variable is measured on the same subject. Repeated measure designs measure the same characteristic(s) on the same individual more than twice. Both designs require special multivariate statistical analyses that are rarely covered in standard statistics books, although there are many books available on multivariate statistics. The difference between these and this book, claim the authors, is that this one is aimed at the "mathematically naive." The purpose is to give three skills to researchers who may not have the mathematical background needed to easily understand multivariate statistics: 1) understand the concepts well enough to correctly frame research questions that will require multivariate statistics; 2) use computer packages for analysis; and 3) be able to communicate effectively with a statistician. The book assumes familiarity with univariate statistics, particularly analysis of variance and regression. The book is organized in two parts. The first is largely in textual form, sprinkled with simple examples, with the objective of providing an explanation uninterrupted by long or complex examples. The second half of the book uses eight studies to illustrate the use of the concepts introduced in the first half. The book is designed for those in the behavioral sciences; thus, all of the examples are from that field. These can be fairly easily translated into biological examples, and the concepts are the same.

analysis, ANOVA, MANOVA, repeated measures analysis, statistics overview, multivariate analysis.

512. Hanley, T. A. 1978. **A comparison of the line-interception and quadrat estimation methods of**

determining shrub canopy coverage. Journal of Range Management. 31: 60-62.

Canopy coverage measured along ten 30m parallel lines and ocularly estimated in forty 20x50cm quadrats was compared at four sites. Measurements were also compared between observers. There were no significant differences in the means between the two methods, or between investigators. To achieve an estimation within 20% of the mean with a 90% confidence interval would, however, require 471 quadrats (118 minutes to sample) and nineteen 30m transect lines (63 minutes to sample) at 8% cover. At 26% cover, 97 quadrats (34 minutes) and 6 lines (29 minutes) would be required. The author concluded that when it was important to have reliable estimates, line intercept was more efficient.

cover, field techniques, canopy cover, line intercept, cover classes, shrubland, shrub grassland, ocular estimation, observer variability, precision, technique comparison.

513. Hansjorg, D.; Steinlein, T. 1996. **Determination of plant species cover by means of image analysis**. Journal of Vegetation Science. 7: 131-136.

field techniques, charting, demographic techniques, cover, cover classes, point intercept, ocular estimation, photoplots.

514. Hanson, H. C. 1934. **A comparison of methods of botanical analysis of the native prairie in western North Dakota**. Journal of Agricultural Research. 49: 815-842.

Measures of cover (visual estimation, "area-list," and point intercept), frequency, density, and standing crop (clipped plots) of grassland species were completed in 8x5dm plots, each divided into four 2.5x4dm subplots. This design allowed for grouping of the four subplots into plots of various sizes and configurations. Variance of density estimates decreased with larger plot sizes, but not enough to warrant the extra sampling costs of larger plots. Variance was also smaller when the sampling area was distributed among 2.5x4dm plots compared to half the number of 2.5x8dm plots, but the study did not account for travel time between plots. In the clipping study, the variability between means of the 8x5dm plots was greater than that between the four subplots, illustrating the heterogeneous nature of the stand. In comparison of clipped composition, frequency, and point intercept, the frequency method gave the largest relative percentage for forbs, the point intercept the least. Relative percent of sod forming grasses was estimated highest by the point intercept compared to the other methods.

field techniques, sampling design, plot selection, density, grassland, plot dimensions, technique comparison, frequency, charting, point intercept, canopy cover, cover, design.

515. Hargrove, W. W.; Pickering, J. 1992. **Pseudoreplication: a *sine qua non* for regional ecology?** Landscape Ecology. 6: 251-258.

sampling design, design, pseudoreplication, landscape-level.

516. Harniss, R. O.; Murray, R. B. 1976. **Reducing bias in dry leaf weight estimates of big sagebrush**. Journal of Range Management. 29: 430-432.

field techniques, production, shrub, biomass.

517. Harrington, G. N. 1979. **Estimation of above-ground biomass of trees and shrubs**. Australian Journal of Botany. 27: 135-143.

field techniques, biomass, production, tree, shrub, forest, shrubland.

518. Harris, R. 1987. **Satellite remote sensing: an introduction**. New York, NY: Chapman and Hall. 220 p.

Although somewhat dated, this book provides a good overview of standard remote sensors such as Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM). Explanation of the basic theory of energy reflectance from the earth's surface and capture by satellite-based sensors is included in sufficient detail for the uninitiated. The recording of data by digital image processing is also described. The chapter "Land cover and vegetation" is especially applicable to vegetation monitoring. It describes with examples the use of remote sensing data to estimate vegetation production, map and monitor range vegetation, classify woodlands and forest types, detect damage and disease in forests, and monitor expansion of the urban boundary.

landscape-level, pattern, landscape change, pattern, regional planning, cover typing, Landsat, TM, MSS, remote sensing, large-scale monitoring.

519. Harris, R. B.; McGuire, L. A. 1987. **Sample sizes for minimum viable population estimation**. Conservation Biology. 1(1): 72-76.

design, sample size.

520. Harrison, A. E. 1974. **Reoccupying unmarked camera stations for geological observations**. Geology. 2: 469-471.

This paper describes a method for exact relocation (within a 1% accuracy) of unmarked camera stations. This method may be useful in relocating stations of historic photographs for use in long-term photographic monitoring.

field techniques, photopoints, long-term ecological monitoring.

521. Hart, R. H.; Laycock, W. A. 1996. **Repeat photography on range and forest lands in the western United States**. Journal of Range Management. 49: 60-67.

This bibliography lists 175 publications that use repeat photography. A table lists publications by state and ecosystem type. The annotated bibliography lists the reference and describes the number and dates of repeat series, the habitat, and the state where the photographs were taken.

photopoints, field techniques.

522. Haslett, J. R. 1990. **Geographic information systems: a new approach to habitat definition and the study of distributions**. Trends In Ecology and Evolution. 5: 214-218.
GIS.

523. Hatton, T. J.; West, N. E.; Johnson, P. S. 1986. **Relationship of the error associated with ocular estimation and actual total cover**. Journal of Range Management. 39: 91-92.

Authors constructed 20 "quadrats"(posterboard) with coverage by paper ranging from 0.36-97.3% cover. For each quadrat, 24 individuals estimated the percent cover. The percent error (difference between estimated cover and real cover) was highest at the lowest cover values. The variability of observations was highest at the middle cover values, peaking at approximately 55% cover. The authors suggest that cover estimation classes should be relatively narrow at extreme cover values and wider in the intermediate ranges of cover.

cover, field techniques, canopy cover, ocular estimation, observer variability, cover classes.

524. Haug, P. T. 1983. **Resource inventory and monitoring under NEPA**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 261-265.

This paper presents a framework for inventory and monitoring of temporal and spatial change caused by an act of man (environmental impact). Inventory and monitoring are recognized as two complimentary activities: the inventory measures current condition as a benchmark from which to measure change through monitoring. Monitoring measures effects and/or compliance with laws, regulations, and standards. Effective inventory and monitoring requires: 1) selecting informative and measurable parameters; 2) developing hypotheses or models so that the type of change expected can be monitored; 3) designing monitoring such that hypotheses are tested using classical experimental approaches; and 4) using monitoring in decision making and adaptive management. The author presents a worksheet approach for identifying change agents, the quantity, type, and probability of change in an indicator, and the relative importance of that change.

inventory, monitoring overviews, indicators, monitoring and management, experimental design, adaptive management.

525. Hawk, G. M.; Franklin, J. F.; McKee, W. A.; Brown, R. B. 1978. **The H.J. Andrews Experimental Forest reference stand system: establishment and use history**. Bull. 12. Seattle, WA: U.S. International Biological Program, Coniferous Forest Biome, Ecosystem Analysis Studies, University of Washington. 79 p.

This publication describes the reference stand methodology for characterizing and monitoring major plant communities in the western hemlock - pacific silver fir vegetation zones of the Cascade Mountains of Oregon. As part of the International Biological Program (IBP), Coniferous Forest Biome Project, 19 reference stands were established in the early 1970s. Near modal representatives of major plant communities were selected as reference stands, encompassing most of the observed vegetative and environmental variation. The entire reference stand was divided into a 10x10m grid and monumented with permanent metal stakes. All trees (>5cm dbh) were mapped, tagged, and measured (DBH, vigor, crown condition, and bole condition). Downed logs and stumps were also mapped for each stand. Saplings were tallied within 30x30m subplots. Smaller nested plots, of various sizes, were used to tally seedlings, and record cover and frequency measurements for shrub and herbaceous species. Data were also collected to develop index estimates of understory biomass and leaf area. Air and soil temperatures were measured with a thermograph. Analysis of the initial set of data collected is reported in this publication, including summary cover and size class distribution tables, detailed stand and site descriptions, and maps. The authors also discuss how these reference stands have been utilized as baselines and for other research purposes from 1972-1977.

special sites, field techniques, monitoring examples, permanent plots, reference areas, baseline monitoring, long-term ecological monitoring, natural areas, monumentation, forest, DBH, tree, cover, frequency, integrated monitoring, soils.

526. Hawkins, C. P. 1986. **Pseudo-understanding of pseudoreplication: a cautionary note**. Bulletin of The Ecological Society of America. 67: 185.

Ecological experiments without replicates are common because of the unavailability or expense of replications. These studies can still be very valuable if other information is available to infer treatment effects, relying on statistics only to show significant differences.

design, biological significance, pseudoreplication, replication.

527. Haydock, K. P.; Shaw, N. H. 1975. **The comparative yield method for estimating dry matter yield of pasture**. Australian Journal of Experimental and Agricultural Animal Husbandry. 15: 663-670.

field techniques, biomass, production, grassland, herbaceous species.

528. Hayes, J. A. 1995. **A bitterbrush dieback in the upper Gunnison River Basin, Colorado**. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 189-191.

During the drought period of 1988-1993, bitterbrush in a 500 mile^2 area in Colorado experienced widespread dieback. The area was reconnaissanced, and sites of significant

die-back identified (54 sites). Within each site, a representative area was selected by ocular estimate. Cover was estimated by a 200ft line-intercept transect subjectively placed within the site. The percent of dead branches of each bitterbrush along the transect was estimated. This method of sampling a large-scale phenomenon may be appropriate to other situations.

landscape-level, general examples, shrub, line intercept, disturbance, landscape change, pattern, field techniques, cover, shrub grassland, canopy cover, large-scale monitoring.

529. Hayne, D. W. 1987. **Development of environmental data bases and inventories**. In: Draggan, S.; Cohrssen, J. J.; Morrison, R. E., eds. Environmental monitoring, assessment, and management. The agenda for long-term research and development. New York, NY: Praeger Publishers: 21-35.

The first advice in this article is to see a statistician early in the design of a monitoring program. Decisions must be made on what to monitor (balancing the need for data and the cost), where to monitor, when to monitor, and how often to monitor. A critical decision is whether the objective is an index value (one resulting from sampling carried out at sites or times selected by judgement) or an unbiased estimate that results from standard probability sampling. If the latter, a consideration of design and costs must be made. A discussion and formulas for calculating optimal sampling strategies in two-stage and three-stage designs are presented.

design, objectives, sampling design, random sampling, stratified sampling.

530. Hazlett, D. L. 1994. **Vegetation monitoring guidelines for the intermountain wilderness area and ecosystem study**. Fort Collins, CO: U.S. Department of Interior, National Biological Survey, Environmental Science and Technology Center.

This publication describes the Intermountain Wilderness Area and Ecosystem Study vegetation monitoring program established by Bureau of Land Management.

special sites, monitoring examples, wilderness, monitoring overviews, ecological monitoring programs, long-term ecological monitoring.

531. Heady, H. F. 1957. **The measurement and value of plant height in the study of herbaceous vegetation**. Ecology. 38: 313-320.

The author illustrates that plant height is often not a simple measure to use. Plant morphology such as trailing or drooping, leaning, and pedestalled plants make consistent measures difficult. Plants that are rhizomatous pose the additional problem of determining what is the individual. The measure used for height in published literature is variable, including tallest height, mean height, and height of the main mass of vegetation (excluding, for example, seedheads). Height is defined in this paper as the "perpendicular distance from the soil at its base to the highest point reached with all parts in their natural position." The author suggests that point frames, similar to those used for measuring cover, can be used to measure plant height. Heights are measured at the highest intersection of the pin with vegetation, and can be sampled either by species or by live plant material in general. This method has been found to work well in the California annual grassland type to compare areas, years, and treatments.

field techniques, herbaceous species, heights, performance, grassland, production.

532. Heady, H. F.; Gibbens, R. P.; Powell, R. W. 1959. **A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation**. Journal of Range Management. 12: 180-188.

Canopy cover was measured with 3 methods in a southeastern California mixed brush community. Canopies were mapped in quadrats 10ft on a side in 3 square macroplots, each 100ft on a side. Each macroplot was also sampled with 20 or 40 transects (100ft long) using the line intercept method and 100 point intercepts for each transect. Mean cover measured by the 3 methods was very similar. The variance was highest for the charted plots, and for most species would require 4x or more sampling units compared to line intercepts, which crossed small scale variation in shrub cover. The authors write: "The principle of long narrow plots being better than square plots has been well established and is futher strengthened by these results." The charting method also overestimated cover due to inclusion of gaps smaller than 2in. Line intercept gave better results than points for species with low cover (3% or less), but neither method was entirely satisfactory. Both methods gave similar results, with similar precision, for species with higher cover. Point intercepts, however, required about half the time in the field compared to line intercept, and less time in the office.

field techniques, cover, density, shrub grassland, canopy cover, charting, line intercept, point intercept, technique comparison, shrub, shrubland.

533. Heady, H. F.; Rader, L. 1958. **Modifications of the point frame**. Journal of Range Management. 11: 95-96.

Authors describe the construction of a point frame for sampling cover, 14 feet long with 10 pins. Leather brakes provide enough friction to hold pins in place, but allow for gradual lowering until contact is made with vegetation.

field techniques, canopy cover, cover, point frames, tools.

534. Heidelbaugh, W. S.; Nelson, W. G. 1996. **A power analysis of methods for assessment of change in seagrass cover**. Aquatic Botany. 53: 227-233.

This is a unique approach, in which the power of three methods of estimating vegetation change is used as a standard of efficiency. The time required to determine two levels of change (10% and 50%) at two levels of power (0.75 and 0.90) using blade counts, biomass measures, and percent cover estimation in quadrats was compared. Percent cover estimation in quadrats required the fewest sampling units, and the lowest sampling effort.

pilot study, technique comparison, density, biomass, cover, cover classes, ocular estimation, field techniques, power.

535. Heintz, T. W.; Lewis, J. K.; Waller, S. S. 1979. **Low-level aerial photography as a management and research tool for range inventory**. Journal of Range Management. 32: 247-249.

aerial photography, remote sensing, rangeland, inventory.

536. Heltshe, J. F.; DiConzio, J. 1985. **Power study of jack-knifed diversity indices to detect change**. Journal of Environmental Management. 21: 331-341.

Eleven simulated plant communities were created with clumped distribution ("parents" with clustered "offspring"). All communities contained about 5600 individuals and 25 species, but the proportional abundance of each differed. Simulated communities ranged from low to high skewness, with skewness defined as the proportion of the total species abundance centered in a few species. From each community, a sample was drawn, yielding a species list and count per quadrat of each species. Determination of standard error of the point estimate of various diversity indices for each sample was done using a jackknife procedure (Heltshe and Forrester 1983). Of primary interest in this paper was the use of jackknifed diversity indices in two-sample hypothesis tests and the power of such tests to detect changes or differences in population diversity. Samples from each of the 11 populations were paired with the sixth population (which had intermediate skewness), and a test of the null hypothesis of no difference tested with a t-test and the Wilcoxon rank sum test. Power was defined as the number of times in 200 trials that the null hypothesis of diversity equality between two communities was rejected.

community-level, community change, species lists, species richness, power, detecting change, jackknife, randomization tests, analysis, design, community composition, diversity indices.

537. Heltshe, J. F.; Forrester, N. E. 1983. **Estimating species richness using the jackknife procedure**. Biometrics. 39: 1-11.

It is extremely difficult to sample random individuals in a population, thus most sampling is of random space in quadrats. Here the authors develop an estimation procedure for the sampling error associated with an estimate of species richness from a random sample of quadrats. The jackknifed estimate is based on the distribution of number of species (psuedo-values) given resampled groups of n-1 from the total of n sampled quadrats in which presence or absence of each species has been noted. Simulations were compared using populations of two different species richness and two levels of skewness (high skewness describes a community with a few dominant species and many rare ones) sampled with different quadrat sizes. The jackknife estimator performed well over much of the range of species richness and skewness, but underestimated the number of species when there were a many rare species in the population. At larger sample sizes (100+ quadrats), the standard estimator outperformed the jackknifed one. With the smaller sample sizes typical of most studies, the jackknifed procedure is advantageous.

analysis, design, community-level, species diversity, species richness, precision, confidence intervals, jackknife, randomization tests, diversity indices.

538. Hennessy, J. T.; Gibbens, R. P.; Tromble, J. M.; Cardenas, M. 1983. **Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico**. Journal of Range Management. 36: 370-374.

general examples, grassland, woodland, detecting change, vegetation mapping, density, frequency, herbaceous species, field techniques, design.

539. Henry, J. D.; Swan, J. M. A. 1974. **Reconstructing forest history from live and dead plant material--an approach to the study of forest succession in southwest New Hampshire**. Ecology. 55: 772-783.

succession, community change, community-level, predicting change, natural variability, forest.

540. Herbin, T. 1996. **Permanent plots as tools for plant community ecology**. Journal of Vegetation Science. 7: 195-202.

permanent plots, ecological models.

541. Herricks, E. E.; Schaeffer, D. J. 1985. **Can we optimize biomonitoring?** Environmental Management. 9: 487-492.

monitoring overviews, indicators, objectives.

542. Herrmann, R. 1990. **The NPS inventory & monitoring initiative: a hierarchial strategy**. Park Science. 9: 10.

This paper gives a general description of the National Park Service's inventory and monitoring program.

monitoring examples, special sites, national parks, natural areas, inventory.

543. Herrmann, R.; Bratton, S. P. 1977. **Great Smoky Mountains National Park as a biosphere reserve: a research/monitoring perspective**. Research/Resources Management Rep. 23. Atlanta, GA: U.S. Department of Interior, National Park Service, Southeast Region. 38 p.

special sites, monitoring examples, national parks, monitoring overviews.

544. Heyer, W. R.; Donnelly, M. A.; McDiarmid, R. W.; Hayek, S. C.; Foster, M. S. 1994. **Measuring and monitoring biological diversity**. Washington, DC: Smithsonian Institution Press. 364 p.

This book is the first in a series to be published by the Smithsonian on ecological monitoring. The editors bring together a number of experts on monitoring amphibians, both as contributors and authors. Chapters include information on sampling considerations and research design, standard

techniques for measuring population sizes, recommendations for analysis of biodiversity data, and several appendices on subjects such as handling live amphibians, preparing specimens, collecting tissue, locating specialized equipment, and other technical information. Some of the chapters are applicable to vegetation monitoring, such one titled "Keys to a successful project" chapter, and several data analysis chapters. The volume specific to vegetation monitoring will be eagerly anticipated.

general book on monitoring, monitoring definitions, monitoring overviews, objectives, design, analysis.

545. Heyting, A. 1968. **Discussion and development of the point-centered quarter method of sampling grassland vegetation**. Journal of Range Management. 21: 370-380.

A small handmade instrument, designed for measurement in grasslands, is described. The instrument makes it easy to measure the distance between the nearest plant and the sampling point for the point-center quarter (PCQ) method of density estimation. Two summary measures are described: 1) "relative frequency" is the number of stations at which the species is recorded at least once; 2) "relative density" is the proportion of all quarters occupied by the species. The authors point out that calculating the mean area per plant, the original purpose of the PCQ method, is rarely appropriate because of the contagious distribution of most species in grassland systems.

field techniques, herbaceous species, community-level, tools, density, technique comparison, community composition, grassland, point-center methods, distance methods, frequency.

546. Hicks, B. B.; Brydges, T. G. 1994. **A strategy for integrated monitoring**. Environmental Management. 18: 1-12.

This forum paper is based on work of the International Air Quality Advisory Board and written by two air resource specialists. Presented is a convincing case for the importance of integrated monitoring programs for understanding complex ecological and environmental relationships (air, water, soil, flora, fauna, etc.). The authors provide many examples of monitoring efforts that have benefitted from multi-disciplinary studies conducted on the same site. They advocate nestinginterdisciplinary monitoring efforts together in the same locations to better link monitoring efforts and to improve opportunities for detecting and understanding more complex relationships. Also presented are workshop results and recommendations on integrated monitoring.

monitoring examples, objectives, interdisciplinary design, large-scale monitoring, ecological monitoring programs, integrated monitoring.

547. Hilborn, R.; Walters, C. J. 1981. **Pitfalls of environmental baseline and process studies**. Environmental Impact Assessment Review. 2(3): 265-278.

This paper was written in response to the evolving environmental assessment process in the late 1970s and early 1980s. At that time, managers and scientists identified the need for baseline and process studies yielding information on ecological conditions over time, instead of point-in-time studies. Baseline studies are of two forms: long-term studies of unperturbed systems to establish natural baselines, and pre-impact baselines combined with post-impact follow-up studies. Process studies are short-term and focus on experimental studies of key ecosystem processes. The authors identify and discuss why baseline and process studies often fail to yield data that allow one to predict environmental impacts. Among the pitfalls are: 1) natural disturbances are rarely similar to the human proposals we wish to implement; 2) problems of variability and control; 3) long-term data needs vs. short-term project timeframes; and 4) the challenge of extrapolating small-scale experiments to larger spatial scales (especially problematic in process studies). The authors make several suggestions to ameliorate the identified problems including thorough documentation of all observations, inclusion of adequate controls, and the use of experimental design to test hypotheses.

monitoring overviews, long-term ecological monitoring, biological significance, objectives, predicting change, detecting change, experimental design, design.

548. Hinds. W. T. 1984. **Towards monitoring of long-term trends in terrestrial ecosystems**. Environmental Conservation. 11: 11-18.

This is an excellent overview of the development of a monitoring strategy. The author defines ecological monitoring as the "purposeful and repeated examination of the state or condition of specifically-defined biotic groups in relation to external stress." Three challenges must be met to design long-term monitoring: 1) selecting biological components or functions within the continuous spatial and temporal variability of the real world; 2) identifying appropriate replication "in a world that is full of unique places;" and 3) meeting the expense of "ecologically relevant, statistically credible" monitoring. The author provides a process for development of monitoring methods that involves the choice of ecosystem units, consideration of error (both Type I and Type II), replication, and design of cost-effective sampling. A flow chart is presented as an aid to developing effective, long-term monitoring.

design, monitoring definitions, power, Type I and Type II errors, objectives, pilot study, monitoring overviews, sampling design.

549. Hironaka, M. 1985. **Frequency approaches to monitor rangeland vegetation**. In: Krueger, W. C., chairman. Symposium on the use of frequency and density for rangeland monitoring: proceedings of the 38th annual meeting, Society for Range Management; 1985 February; Salt Lake City, UT. Denver, CO: Society for Range Management: 84-86.

field techniques, grassland, herbaceous species, community-level, community change, community composition, rangeland, frequency, nested frequency.

550. Hirsch, A. 1980. **Monitoring cause and effects of ecosystem change**. In Worf, D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D. C. Health and Company: 137-142.

Four kinds of monitoring to assess ecosystem status and trend are identified: 1) measuring loss or gain of ecosystem types at the landscape level, such as tropical rain forest or wetlands; 2) assessing the extent and significance of a known contaminant or stress; 3) detecting subtle changes such as those resulting from climate change or acid rain; and 4) identifying unexpected but unacceptable changes in ecosystem function. This last issue, that of ecosystem function and health, is extremely difficult to monitor because of the complexity, the range of natural variability, and the effects of natural catastrophes. Such monitoring is of necessity long-term, but the academic and political institutional support is lacking for long-term studies. Several programs show promise: The Man and the Biosphere (United Nations), National Environmental Research Parks (Department of Energy), and a network of estuarine sanctuaries (National Oceanic and Atmospheric Administration). The passage of the National Environmental Policy Act stimulated the funding of ecological research, but much of this has been spent on "safe descriptive data collection--studies which are often misguided, misdirected and mediocre," serving neither the understanding of long-term impacts nor the needs of immediate decision-making.

monitoring overviews, global change monitoring, ecological monitoring programs, ecosystem management, monitoring definitions, monitoring and management, resource management, monitoring examples, landscape change, long-term ecological monitoring.

551. Hirsch, R. M.; Slack, J. R. 1984. **A nonparametric trend test for seasonal data with serial dependence**. Water Resources Research. 20: 727-732.

trend analysis, analysis, time series.

552. Hirsch, R. M.; Slack, J. R.; Smith, R. A. 1982. **Techniques of trend analysis for monthly water quality data.** Water Resources Research. 18: 107-121.

trend analysis, analysis, time series.

553. Hirst, S. M. 1983. **Ecological and institutional bases for long-term monitoring of fish and wildlife populations**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 175-178.

Successful monitoring is statistically valid, ecologically informative, sensitive to changes, and cost effective. Few monitoring projects meet these characteristics of success usually because of failure to include one the following elements during design: clearly defined objectives, development of models, and a process of periodic assessment, validation, and feedback. Models, either explicit or subconscious, are part of every monitoring project and are usually characterized by being simple, correlated to causes, dynamic (incorporating temporal variability), discrete (reflecting periodic measurement), and analyzed either statistically or by simulation. Institutionally, continued support for a monitoring project, for which costs are incurred immediately but benefits not realized for several or more years, is aided by: 1) choosing monitored attributes with economic value; 2) making the decision implications of the data understood from the outset; 3) ensuring organizational support rather than individual; and 4) providing periodic review.

monitoring examples, ecological monitoring programs, monitoring overviews, ecological models, feedback loops, monitoring and management, objectives.

554. Hobbs, A. J.; Shennan, I. 1986. **Remote sensing of salt marsh reclamation in the Wash, England.** Journal of Coastal Research. 2: 181-198.

remote sensing, vegetation mapping, landscape-level, community-level, wetland, restoration.

555. Hodgson, J.; Baker, R. D.; Davies, A.; Laidlaw, A. S.; Leaver, J. D., eds. 1981. **Sward measurement handbook.** Hurley: The British Grassland Society. 277 p.

vegetation sampling overview, field techniques, grassland, herbaceous species.

556. Hoel, P. G. 1943. **The accuracy of sampling methods in ecology**. Annals of Mathematics and Statistics. 14: 289-300.

design, sampling design, precision, field techniques, density, frequency, cover.

557. Hoener, D.; Greuter, W. 1988. **Plant population dynamics and species turnover on small islands near Karpathos (South Aegean, Greece)**. Vegetatio. 77: 129-137.

community-level, species lists, species diversity, species richness, community change, detecting change.

558. Hofmann, L.; Ries, R. E. 1990. **An evaluation of sample adequacy for point analysis of ground cover.** Journal of Range Management. 43: 545-549.

Using a standard cover point frame (10 pins spaced 5cm apart), the authors determined the number of samples needed to estimate mean cover to within 10% with a 90% confidence interval. Authors found that with high cover values (over 70%), 10 or fewer frames could adequately estimate cover. With small cover values, up to 10,000 frames were necessary due to the large number of frames that had no pins intercepting vegetation. (See Ortiz and Amers (1992) for a critique of this paper.)

design, sampling design, point frames, grassland, rangeland, herbaceous species, cover, canopy cover, point intercept, precision, field techniques.

559. Holechek, J. L.; Stephenson, T. 1983. **Comparison of big sagebrush vegetation in north central New Mexico under moderately grazed and grazing excluded conditions**. Journal of Range Management. 36: 455-456.
community-level, community change, shrubland, community comparisons, general examples, canopy cover, field techniques, cover.

560. Holgate, P. 1964. **The efficiency of nearest neighbor estimators**. Biometrics. 20: 647-649.
The author compares the efficiency of the nearest neighbor distance measure with quadrats. If the average distance from a sampling point to its nearest neighbor is considered to define the radius of a quadrat, then the efficiency of a distance measure can be compared to that of quadrats of an equal total area. This approach assumes the majority of the field time requirements can be captured in terms of area of ground searched. With this assumption, the nearest neighbor technique is only slightly superior to quadrats, and this advantage decreases rapidly as sample size increases.
field techniques, density, plotless methods, nearest neighbor, technique comparison.

561. Holland, M. M.; Risser, P. G.; Naiman, R. J. 1991. **Ecotones**. New York, NY: Chapman and Hall. 142 p.
community-level, community composition, vegetation mapping, landscape-level, pattern, ecotones.

562. Hollander, M.; Wolfe, D. A. 1973. **Nonparametric statistical methods**. New York, NY: Wiley and Sons. 503 p.
analysis, statistics overview, nonparametric statistics.

563. Holling, C. S., ed. 1978. **Adaptive environmental assessment and management**. New York, NY: John Wiley and Sons. 377 p.
This book is often cited in the environmental monitoring literature. Its primary objective is to advance integration of environmental design with economic and social activities from the beginning of a project. Recognizing that in most countries, environmental issues are addressed after the design phase in an environmental impact statement, the authors describe the adaptive management process in which the uncertainty involved in predicting environmental effects is treated as an experiment, and activities are modified depending on the outcome of the experiment. Five themes are discussed: 1) present practice; 2) historical overview of the evolution of the present practice; 3) uncertainty and the problems caused by present practice in environmental assessment; 4) stability and resilience of ecosystems; 5) successful processes and techniques. This last theme is illustrated with five case studies.
objectives, monitoring overviews, monitoring examples, feedback loops, monitoring and management, adaptive management.

564. Holling, C. S. 1993. **Investing in research for sustainability**. Ecological Applications. 3: 553-555.
monitoring overviews, adaptive management.

565. Holm, A. M.; Burnside, D. G.; Mitchell, A. A. 1987. **The development of a system for monitoring trend in range conditions in the arid shrublands of western Australia**. Australian Rangeland Journal. 9: 14-20.
community-level, community change, detecting change, design, monitoring examples, rangeland, grassland, shrub grassland, long-term ecological monitoring, ecological monitoring programs.

566. Holm, A. M.; Curry, P. J.; Wallace, J. F. 1984. **Observer differences in transect counts, cover estimates and plant size measurements on range monitoring sites in arid shrubland.** Australian Rangeland Journal. 6: 98-102.
field techniques, cover, density, observer variability.

567. Holt, R. D.; Robinson, G. R.; Gaines, M. S. 1995. **Vegetation dynamics in an experimentally fragmented landscape.** Ecology. 76: 1610-1624.
The authors report on 6 years of old field succession in an experimentally fragmented landscape. Three replicated patch sizes were monitored with permanent $1m^2$ plots in which cover of each species was estimated using a point intercept. Initially dominant species continued to dominate after 6 years, although their proportions varied by patch size. Larger patches were more species-rich at the end of 6 years, and contained more unique species. Populations of clonal species were more prone to disappear from the smaller patches than from larger. Summary measures of temporal community change, however, did not reflect any significant differences between the patches, and the authors concluded that patch size did not alter the rate or pattern of early succession.
landscape-level, community-level, pattern, fragmentation, disturbance, community change, cover, point intercept, succession.

568. Hope-Simpson, J. F. 1940. **On the errors in the ordinary use of subjective frequency estimations in grasslands**. Journal of Ecology. 28: 193-209.
Differences in subjective frequency measures (rare, local, occasional, frequent, abundant, very abundant, co-dominant and dominant) measured each year are due to differences between observers, annual variation, seasonal change, and site variability. These factors were investigated in 0.1ha plots in several chalk grasslands. In samples repeated by the same observer within a few days, the percent of total species that were found on both occasions was 83%. On both sampling occasions, 8% of the species found were missed in the other sample. Similarity between frequency estimates was exact for only 44% of the species, approximate (one class removed) for 8% and intermediate (2 classes removed) for 36%. Growing season also had an effect. Only 77% of the total number of species were found in both of two samples measured at the beginning and end of the growing season and only 32% of the frequency estimates were in exact agreement.

field techniques, community-level, species richness, species lists, species diversity, cover, observer variability, ocular estimation, cover classes, grassland.

569. Hopkins, A. J. M.; Brown, J. M.; Goodsell, J. T. 1987. **Monitoring system for use in the management of natural areas in western Australia**. In: Saunders, D. A.; Arnold, G. W.; Burbidge, A. A.; Hopkins, A. J. M., eds. Nature conservation: the role of remnants of native vegetation. Canberra, Australia: Surrey Beatty and Sons Limited in association with CSIRO and CALM: 337-339.

This paper describes a monitoring system being developed for national parks, nature reserves, and state forests in western Australia. This system has very broad objectives: 1) provide data on long-term changes in natural communities with a standardized approach; 2) complement the biological survey program; 3) provide a simple and effective method for assessing effects of present management decisions; and 4) increase interest and participation in particular parks or areas through involvement in the monitoring program. A single method was selected for application in all situations. A permanently marked square macroplot is used, typically 20x20m. Photopoints accompany each macroplot. Nested plots within the larger macroplot are utilized to record presence/absence data. Canopy cover is recorded along 4 line intercepts. A single macroplot forms the basis for evaluating each particular community of interest. Although the authors list examples of specific monitoring projects and objectives, they provide no discussion on statistical aspects of design and data analysis.

monitoring examples, special sites, field techniques, cover, natural areas, ecological monitoring programs, long-term ecological monitoring, permanent plots, photopoints, frequency, canopy cover, line intercept, objectives.

570. Hormay, A. L. 1949. **Getting better records of vegetative changes with the line interception method**. Journal of Range Management. 2: 67-69.

Consistency between observers in measuring cover by line intercepts can be improved by adopting a rule for dealing with interspaces. The first choice is whether to consider the entire plant the unit or to use a subunit such as a fasicle of leaves and flowering stems that emerges from one of the buds on the root crown. If the plant is chosen as the unit, as is recommended here, "normal" interspaces within the plant crown would be measured as vegetation. These "normal" interspaces between leaves or stems in a clonal herbaceous species, and the normal size of openings in a crown canopy of a shrub or basal canopy of a tuft are evaluated at a site based on the average size of interspaces in most plants. These spaces are ignored when measuring line intercept cover; abnormally large interspaces are recorded as litter or bare ground. The author suggests that line intercept cover values can be used with clipped biomass values to determine percent composition. The more rapidly measured line intercept values can be used to increase the sample size.

technique comparison, field techniques, canopy cover, cover, basal area, line intercept, biomass, production, weight estimate, community composition, community-level, observer variability.

571. Horton, J. S. 1941. **The sample plot as a method of quantitative analysis of chaparral vegetation in southern California**. Ecology. 35: 244-262.

field techniques, density, shrubland.

572. Hough, A. F. 1965. **A twenty-year record of understory vegetation change in a virgin Pennsylvania forest**. Ecology. 46(3): 370-373.

This older study illustrates the value of photographic techniques for long-term monitoring of vegetation changes. Permanent photo plots were established in 1941 and monitored over a 20-year period to detect changes in understory vegetation in an old-growth hemlock-hardwood forest. Twenty-one milacre quadrats were arranged along a 3 1/4 mile long transect, encompassing plant communities along an elevational gradient. Both color and black and white photographs were used to document changes in species composition and effects of deer browsing over the time period. Plant species were identified from the photographs.

field techniques, general examples, photoplots, permanent plots, long-term ecological monitoring.

573. Hovind, H. J.; Rieck, C. E. 1970. **Basal area and point-sampling: interpretation and application**. Tech. Bull. 52. Madison, WI: Wisconsin Conservation Department. 52 p.

sampling design, design, basal area, tree, forest.

574. Howald, A. M.; Antonio, C. C. 1990. **Designing a monitoring program for a native plant community revegetation project**. In: Hughes, H. G.; Bonnicksen, T. M., eds. Restoration '89: the new management challenge; 1989 January 16-20; Oakland, CA. Madison, WI: Society for Ecological Restoration: 182-193.

This paper describes a program developed to monitor success of native plant community restoration following construction of a buried oil pipeline through California coastal communities. Of particular interest is the discussion of management objectives and monitoring criteria. Prior to initiation of monitoring, the authors identified the management goals and established criteria for determining whether or not reclamation as measured by monitoring was acceptable, or if there was need for additional management action. For example, a management goal of 70% plant cover within 2 years was identified for grassland communities. The restoration effort was considered successful in the first year if >50% cover was recorded. If not, remedial action to control erosion was taken. Only limited information was presented on field sampling methodologies.

monitoring examples, objectives, restoration, feedback loops, monitoring and management, adaptive management.

575. Hughes, E. E. 1962. **Estimating herbage production using inclined point frames.** Journal of Range Management. 15: 323-325.

field techniques, production, point intercept, cover, point frames, technique comparison.

576. Hughes, H. G.; Varner, L. W.; Blankenship, L. H. 1987. **Estimating shrub production from plant dimensions.** Journal of Range Management. 40: 367-369.

Annual shrub production is often laborious to measure because of the difficulty in separating current growth from previous and because of the variability of shrub form. Individuals of 4 species were measured for maximum crown width, the perpendicular to maximum width, the height of the plant (if below 125cm), and the average height of twigs (if above 125cm). Plant volume was calculated from these measures. Plants were then clipped and the current growth removed, dried, and weighed. Regression of production against maximum crown width (log/log model) yielded coefficients of 87% or better for all 4 species and exhibited a better predictive relationship for production than volume. Other models (linear, logarithmic, exponential, and quadratic) gave much poorer performances.

field techniques, crown diameter, shrubland, production, shrub, heights.

577. Hughes, J. H. 1969. **An evaluation of the dry-weight-rank method of determining species composition of plant communities.** Ft. Collins, CO: Colorado State University. 111 p. Thesis.

field techniques, production, dry-weight-rank, community-level, community composition.

578. Huhta, V. 1979. **Evaluation of different similarity indices as measures of succession in arthropod communities of the forest floor after clear-cutting.** Oecologia. 41: 11-23.

community-level, community change, community comparisons, analysis, similarity measures.

579. Huisman, J.; Olff, H.; Fresco, L. F. M. 1993. **A hierarchial set of models for species response analysis.** Journal of Vegetation Science. 4(1): 37-46.

objectives, ecological models, predicting change.

580. Hulbert, L. C. 1978. **Natural area needs for range research.** In: Hyder, D. N., ed. Proceeding of the 1st International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 263-265.

This paper makes a case for natural areas to serve as reference areas in range research. Eight examples of the kinds of questions that could be addressed with a reference area approach are presented. Characteristics of a good research area include: large size, diversity of topography and soils, natural condition, potential for natural system management (including fire management), and permanently set aside to allow long-term processes to take place.

special sites, natural areas, reference areas, rangeland.

581. Humphrey, C. L.; Faith, D. P.; Dostine, P. L. 1995. **Baseline requirements for assessment of mining impact using biological monitoring.** Australian Journal of Ecology. 20: 150-166.

This paper describes monitoring of aquatic systems for impacts from mining wastes. Two types of monitoring are used. The early warning system is designed to detect effects using captive snails and measurement of heavy metal concentrations in fish and mussels. Long-term monitoring is designed to measure changes in composition of natural communities and populations. The authors outline several benefits and considerations for the use of whole community attributes rather than changes in population abundances of particular indicator organisms. The monitoring program utilizes a BACI design, and a portion of this paper is directed at defending this approach. The authors point out that the major advantage of the BACI approach compared to others such as Random Intervention Analysis (Carpenter 1989) or ANOVA-based models is the ability to both test hypotheses and determine the power of the test and the effect size. The argument that multiple independent control sites are necessary (Underwood 1993) is disputed, because in this situation changes due to elevated heavy metals could only be attributed to mining activities. Inference of causes of statistically detectable differences between impacted sites and control sites can depend on other evidence and biological interpretation just as effectively as on replicated treatment-control pairs. Some suggestions are given for dealing with additional control sites that are more distant from the area of impact (and thus not as effective as controls). In this study, using multivariate dissimilarities as a measure of difference between the treatment and control site was found to be a powerful and sensitive measure of community change within the BACI design. Using the Bray-Curtis measure, a 20% increase in the dissimilarity measure between adjacent control and treatment sites would be detected with only five baseline samples (comparisons). Power can be maintained while reducing this five-year time scale by adopting more liberal levels of α (probability of committing a Type I error). Ecological understanding of changes in community dissimilarity can be aided by 1) ordination to see if post-perturbation samples lie outside the region defined by pre-perturbation samples; 2) comparison to existing disturbances; 3) use of species within the sample whose individual response to perturbation is known; 4) meta-analysis of a number of disturbed and undisturbed sites; and 5) modelling.

special sites, monitoring examples, protected areas, wilderness, design, community change, ecological models, baseline monitoring, monitoring and management, BACI, long-term ecological monitoring, biological significance, statistical interpretation, sampling design, experimental design, multivariate analysis, similarity measures, ordination, Type I and Type II errors, power, precision.

582. Hunsaker, C. T.; Carpenter, D. E.; Messer, J. 1990. **Ecological indicators for regional monitoring**. Bulletin of The Ecological Society of America. 71: 165-172.

The Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency (EPA) is a national integrated monitoring network with the following objectives: 1) estimate current status, extent, changes, and trends in indicators of the condition of the nation's ecological resources; 2) monitor indicators of pollutant exposure and habitat condition, seeking associations between human-induced stressors and ecological condition; and 3) develop periodic statistical summaries and interpretive reports on ecological status and trends. Key to the program is the selection of indicators for monitoring. Five classes of indicators are described: response indicators (ecosystem processes, community, and population structure), pollutant source indicators (atmospheric deposition, discharge, agricultural chemicals, permits), natural processes indicators (succession, climatic fluctuations), management indicators (harvest rates, hydrologic modifications), and exposure-habitat indicators (pathogens, bioassays, exotic organisms). Within each of these classes, potential specific habitat and regional indicators have been identified, and examples for some classes, habitats, and regions are given here. The indicators were chosen based on 11 criteria, such as good correlation with and sensitive response to unmeasured stressors or management strategies, known relationship to overall structure and function of ecosystems, low natural variability, and standard, cost-effective methods of measurement.

integrated monitoring, monitoring examples, ecological monitoring programs, interdisciplinary design, monitoring and management, objectives, ecological processes, ecosystem management, indicators, landscape change, landscape-level.

583. Hunsaker, C. T.; Carpenter, D. E., eds. 1990. **Environmental monitoring and assessment program - ecological indicators.** EPA/600/3-90/060. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development.

This large publication describes ecological indicator concepts and strategies for the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP). One chapter is dedicated to describing the selected indicators and rationale, design objectives and sampling approach, and issues regarding the application of the indicator strategy. Subsequent chapters deal with application of the indicator strategy in various ecosystems: near-coastal waters, inland surface waters, wetlands, forests, arid lands, agroecosystems, multiple resource categories, and atmospheric stressors. Appendices provide detailed indicator fact sheets for each of the ecosystem types.

environmental monitoring programs, monitoring overviews, integrated monitoring, monitoring examples, ecological monitoring programs, interdisciplinary design, monitoring and management, objectives, ecological processes, ecosystem management, indicators, landscape change, landscape-level.

584. Hunsaker, C. T.; O'Neill, R. V.; Jackson, B. L.; Timmins, S. P.; Levine, D. A.; Norton, D. J. 1994. **Sampling to characterize landscape pattern**. Landscape Ecology. 9: 207-226.

landscape-level, pattern, design.

585. Hunt, E. V.; Baker, R. D. 1967. **Practical point sampling**. Bull. 14. Nacogdoches, TX: SFA State College. 43 p.

sampling design, plotless methods, density, tree, forest.

586. Huntley, B. J. 1988. **Conserving and monitoring biotic diversity: some African examples**. In: Wilson, E. O., ed. Biodiversity. Washington, DC: National Academy Press: 248-260.

monitoring examples, biodiversity, ecological monitoring programs, landscape-level.

587. Hurlbert, S. H. 1971. **The nonconcept of species diversity: a critique and alternative parameters**. Ecology. 52: 577-586.

Hurlbert argues that the current use of the term "species diversity" is ambiguous. He recognizes two concepts: species richness or abundance (the number of species present) and species evenness or equitability (the distribution of individuals among these species). Commonly used indices try to combine these two aspects, but vary in the weight given to each. One index, for example, may consider a community of only 6 species, equitably distributed, as more diverse than a community with 91 species, one of which is very abundant. Without using a biological or ecological standard against which to assess the effectiveness of diversity indices, there is no way to judge which ones are best. An alternative is suggested here based on the probability of interspecific encounters. In a community with a large number of widely distributed species (such as a tropical rain forest), the probability of interspecific encounter is much higher than in a community with a few common species. This index has biological interpretation in terms of search time for hosts, forage, mates, or prey. Variations on this index can be used to calculate the ratio of inter- and intraspecific encounters, which could function as a measure of competition. This index combines species richness and evenness characteristics, but considering each separately may also be informative. Species richness can be defined in terms of the expected number of species in a sample of size n from a collection of N individuals of S species (an equation is provided). It remains difficult to compare two communities, however, because as sample size increases, sample species richness increases variably according to the actual number and relative abundance of the species in the collection. Graphical methods comparing species richness/sample size curves may be the most useful. Species evenness can be defined as the ratio of observed diversity to the value of the diversity index if all species were equally abundant. The measure is sample size dependent, decreasing ith increasing sample size because of the addition of single individuals of rare species. In a final

note, the author recommends that diversity estimations are most informative when limited to a group of similar ecology, rather than broadly attempting to estimate the diversity of all life forms within a community or area.

community-level, species lists, biodiversity, community composition, diversity indices, species diversity, species richness, functional groups.

588. Hurlbert, S. H. 1984. **Pseudoreplication and the design of ecological field experiments.** Ecological Monographs. 54: 187-211.

This is a widely cited paper in the ecological literature because it describes so well the problem of pseudoreplication. This common statistical error involves mistaking subsamples for replicates in analysis. Several paired samples collected inside and outside of a grazing exclosure, for example, are not replicates, in that they are not independent observations of the effect of treatment and control. Pseudoreplication is especially prevalent in the ecological literature, because of the difficulty of creating or finding replicates and the high cost of ecological research. This paper is a must-read for those designing any type of ecological sampling program. It is also important for understanding more recent literature that heavily draws on the concepts in this paper.

design, pseudoreplication, sampling design, experimental design, analysis.

589. Husch, B. 1971. **Planning a forest inventory.** FAO Forestry and Forest Products Studies 17. Washington, DC: United Nations, Food and Agriculture Organization. 121 p.

Although designed for forest inventory projects, this document provides guidance on developing objectives applicable to any natural resource information gathering activity.

general examples, tree, forest, inventory, integrated monitoring, sampling design, objectives.

590. Husch, B.; Miller, C. I.; Beers, T. W. 1982. **Forest mensuration.** New York, NY: John Wiley and Sons. 402 p.

field techniques, forest, vegetation sampling overview, tree.

591. Hutchinson, C. F. 1981. **Use of digital Landsat data for integrated survey.** In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 240-249.

The most common approach to the use of Landsat data is to test how well it corresponds to an existing (mapped) land classification system. In this paper, 13 classification systems are summarized, illustrating the different criteria and outcomes of the different systems. Because classifications are man-made constructs, and because mapped polygons have irregularities and inclusions that may muddle a comparison with the per pixel classification of Landsat data, a more fruitful approach may be to allow unsupervised computer classification of the Landsat imagery, and correlate these classes to actual ground features afterward. A test in the Mojave Desert showed that Landsat classes were most influenced by physical characteristics such as soil color, parent material, and elevation. There was little sensitivity to species cover.

general examples, landscape-level, pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, remote sensing.

592. Hutchings, M. J. 1991. **Monitoring plant populations: census as an aid to conservation.** In: Goldsmith, F. B., ed. Monitoring for conservation and ecology. London: Chapman and Hall: 61-76.

rare species, inventory, baseline monitoring, general examples.

593. Hutchings, S. S.; Holmgren, R. C. 1959. **Interception of loop-frequency data as a measure of plant cover.** Ecology. 40: 668-677.

Measurements taken with a 3/4 inch loop, a standard range method of the 1960s, are interpreted as frequency and as an index of cover. Issues associated with the latter are often overlooked. Since the loop has an area, it overestimates cover, and the level of bias is dependent on plant size and plant number. Plants with a radius of 1/16 inch will be overestimated for cover by 49 times the actual percent cover; those with a 1 inch diameter will be overestimated by a factor of 2. At 5 inches, the bias is only a factor at 1.2, and becomes negligible. This bias can be adjusted if either plant density or average plant size is known. The relationship between the loop index and actual plant cover is also affected by plant distribution (random, contagious, or regular) and by the shape of plants. The authors tested the loop method on both artificial and natural populations, and found that the actual levels of bias corresponded closely to the theoretical levels.

field techniques, cover, canopy cover, loop frames, frequency.

594. Hutchings, S. S.; Schmantz, J. E. 1969. **A field test of the relative weight estimate method for determining herbage production.** Journal of Range Management. 22: 408-411.

field techniques, production.

595. Hyder, D. N.; Bement, R. E.; Remmenga, E. E.; Terwilliger, C. Jr. 1965. **Frequency sampling of blue gramma range.** Journal of Range Management. 18: 90-93.

field techniques, frequency, grassland.

596. Hyder, D. N.; Bement, R. E.; Terwilliger, C. 1966. **Vegetation-soils and vegetation-grazing relations from frequency data.** Journal of Range Management. 19: 11-17.

field techniques, frequency, rangeland.

597. Hyder, D. N.; Conrad, C. E.; Tueller, P. T.; Calvin, L. D.; Poulton, C. E.; Sneva, F. A. 1963. **Frequency sampling in sagebrush-bunchgrass vegetation**. Ecology. 44: 740-746.

In testing different plot sizes in sagebrush grass habitats, the authors found that a frequency quadrat of 6 to 10in² was most efficient. Using 10 to 20 of these per transect provided the most efficient distribution.

field techniques, frequency, plot dimensions, plot selection, sampling design, shrub grassland, design, sampling design.

598. Hyder, D. N.; Sneva, F. 1960. **Bitterlich's plotless method for sampling basal ground cover of bunchgrass**. Journal of Range Management. 13: 6-9.

field techniques, cover, variable plots, basal area, grassland.

599. Ibrahim, K. M. 1971. **Ocular point quadrat method**. Journal of Range Management. 24: 312.

field techniques, cover, point intercept.

600. Idle, E. T. 1995. **Conflicting priorities in site management in England**. Biodiversity and Conservation. 4: 929-936.

objectives.

601. Iles, K. 1979. **Some techniques to generalize the use of variable plot and line intersect sampling**. In: Frayer, W. E., ed. Proceedings: forest resource inventories workshop; Fort Collins, CO. Fort Collins, CO: Colorado State University: 270-277.

field techniques, plotless methods, density, tree, forest, line intercept.

602. Iles, K. 1983. **Some thoughts on growth measurement techniques**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 259-260.

Representing a large British Columbia timber company that manages about 3.5 million acres, the author describes techniques that have been successful for monitoring forests. A 2000 permanent plot system is measured by permanent crews. Summer students were found inadequate unless given constant and close supervision. Some plots are recognized as not representative, but are included to meet research and model development needs. Other plots are located randomly to estimate statistically reliable values for commercially important parameters such as growth and yield.

field techniques, design, monitoring examples, observer variability, permanent plots, sampling design, coniferous forest, tree.

603. Iles, K.; Beers, T. W. 1983. **Growth information from variable plot sampling**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 693-695.

The main objection to using permanent variable plots (with a fixed sampling point) is that trees not originally included within the variable plot grow just large enough at the next sampling to be included, thus causing a sudden and fairly large increase in total volume for the plot. One approach is to fix the plot diameter between intervals. Plot size would remain constant between measurement 1 and 2, but at measurement 2 could be changed and measured again, then held constant at that size for measurement 2 and 3. The components of growth can then be segregated into growth and recalibration effect.

permanent plots, tree, forest, basal area, variable plots, field techniques, density, production, permanent plots.

604. Inglis, G.; Underwood, A. J. 1992. **Comments on some designs proposed for experiments on the biological importance of corridors**. Conservation Biology. 6: 581-586.

The authors deal with the specific issue of testing the importance of corridors, but their comments are appropriate to any ecosystem-level experimental design. A common problem is the lack of replicates within randomized blocks, often because too few experimental units are included (or are available) or because of the lack of independence between experimental units. They also point out that in manipulation studies, there may be other effects associated with the manipulation that alter the treatment area other than the intended treatment. Their example is one in which all animals are removed from an area (in order to measure recolonization) but in doing so, the habitat is altered such that the recolonization rate is affected by the alteration.

design, landscape-level, corridors, fragmentation, sampling design, experimental design.

605. Innes, J. L. 1988. **Forest health surveys: problems in assessing observer objectivity**. Canadian Journal of Forest Research. 18: 560-565.

ecological monitoring programs, large-scale monitoring, long-term ecological monitoring, monitoring examples, observer variability.

606. Innes, J. L.; Landmann, G.; Mettendorf, B. 1993. **Consistency of observations of forest tree defoliation in three European countries**. Environmental Monitoring and Assessment. 25: 29-40.

ecological monitoring programs, large-scale monitoring, long-term ecological monitoring, monitoring examples, observer variability.

607. Iremonger, S. F. 1990. **A structural analysis of three Irish wooded wetlands**. Journal of Vegetation Science. 1: 359-366.

community-level, community structure, field techniques, density, heights, cover, basal area, tree, forest, wetland.

608. Iverson, L. R.; Cook, E. A.; Graham, R. L. 1994. **Regional forest cover estimation via remote sensing: the calibration center concept.** Landscape Ecology. 9: 159-174.
landscape-level, pattern, landscape change, remote sensing, forest, cover.

609. Ives, A. R. 1995. **Measuring resilience in stochastic systems.** Ecological Monographs. 65: 217-233.
detecting change, community change, landscape-level, community-level, design, natural variability.

610. Ives, A. R. 1995. **Predicting the response of populations to environmental change.** Ecology. 76: 926-941.
objectives, global change monitoring, ecological models, predicting change.

611. Izrael, Y.; Munn, R. E. 1986. **Monitoring and assessment of ecological change.** In: Clark, W. C.; Munn, R. E., eds. Sustainable development of the biosphere. Cambridge, Massachusetts: Cambridge University Press.
monitoring overviews, monitoring examples, long-term ecological monitoring, monitoring and management, detecting change, design.

612. Jackson, D. A.; Somers, K. M.; Harvey, H. H. 1989. **Similarity coefficients: measures of co-occurrence and association or simply measures of occurrence?** American Naturalist. 133: 436-453.
analysis, similarity measures.

613. Jackson, M. T.; Petty, R. O. 1973. **A simple optical device for measuring vertical projection of tree crowns.** Forest Science. 19: 60-62.
field techniques, tools, tree, crown diameter, cover, canopy cover, forest, line intercept.

614. James, F. C.; McCulloch, C. E. 1990. **Multivariate analysis in ecology and systematics: panacea or Pandora's box?** Annual Review of Ecology and Systematics. 21: 129-166.
analysis, multivariate analysis, ordination, classification, clustering.

615. James, F. C.; Shugart, H. H. 1970. **A quantitative method of habitat description.** Audubon Field Notes. 24: 727-736.
field techniques, distance methods, plotless methods, density, community composition.

616. Jamil, A. T. M.; Alidrisi, M.; Aljiffry, M. S.; Jefri, M. A.; Erturk, R. 1992. **An environmental stress information system.** Environmental Monitoring and Assessment. 22: 213-226.
integrated monitoring, monitoring examples.

617. Janz, K.; Sing, K. D. 1991. **Assessment and monitoring of forest resources.** Tenth World Forestry Congress, actes proceedings. Paris, France: 9-22.
tree, forest, monitoring examples, inventory.

618. Jassby, A. D.; Powell, T. M. 1990. **Detecting change in ecological time series.** Ecology. 71: 2044-2052.
Time series data are often multivariate, containing either several measured properties (vector time series) or several observations of a single variable (e.g., measures of water temperature at several stations; multidimensional time series). The dimensions of the latter can be reduced by principal component analysis, as illustrated in this paper. To determine trend from time series, the data must be decomposed into components of trend, regular oscillations about the trend, fixed seasonal factors, and residual irregular movements. Recently developed distribution-free tests that allow analysis of a wide variety of time series, avoiding the need for decomposition, are referenced here. To detect changes in cyclic behavior, the spectrum of the time series before and after a perturbation can be compared to determine if the frequency or amplitude of the cyclic behavior has changed. To use these methods at least 10 oscillations must be recorded. Other approaches are referenced. Unusual events can be addressed using auto-regressive moving average models or intervention analysis. A key point made is that covariance of time series is insufficient evidence for a causal relationship.
analysis, design, detecting change, covariance, time series, trend analysis, multivariate analysis, nonparametric statistics.

619. Jeffers, J. N. R. 1989. **Environmental monitoring.** Biologist. 36: 171.
monitoring overviews.

620. Jenkins R. E. 1978. **Heritage classification: the elements of ecological diversity.** Nature Conservancy News. 38: 24-25.
special sites, inventory, monitoring examples, global change monitoring, reference areas, objectives, ecosystem management, natural areas, baseline monitoring.

621. Jenkins, R. E. 1996. **Natural heritage data center network: managing information for managing biodiversity.** In: Szaro, R. C.; Johnson, D. W., eds. Biodiversity in managed landscapes. New York, NY: Oxford University Press: 176-192.
Two major biodiversity database systems are currently operational: the Environmental Resources Information Network in Australia and the Natural Heritage Data Centers in the U.S. (also covering Canada, Latin America, and the Caribbean). By 1992, nearly 400,000 element occurrences were being tracked by the U.S. portion of the Heritage Database with an annual investment of $50 to 80 million per year, and a cumulative investment since 1974 of up to $500 million. Jenkins cautions that development of a complex system such as the Heritage database is a lengthy process,

one that continually evolves as problems are identified and solved. Ten questions critical to biodiversity conservation and management have been identified during database development and are discussed in detail: 1) What are the elements of diversity? 2) Which need help? 3) Where are they found? 4) Where should efforts be concentrated? 5) How are elements related to one another? 6) How should or can the elements be managed? 7) What changes are occurring? 8) What are the threats? 9) Who are the actors? and 10) Where can this information be obtained?

design, biodiversity, data management, inventory.

622. Jenkins, R. E.; Bedford, W. B. 1973. **The use of natural areas to establish environmental baselines**. Biological Conservation. 5: 168-174.

The importance of natural areas as environmental baselines is discussed at length in this paper. The authors present the case that before we can appreciate the true effects of ecosystem management and modification, we need to understand how natural ecosystems function. A system of natural areas representing the variety of ecosystems is a necessary requisite to this end. A working definition of baseline is presented as "an accurate description of the status and workings of an ecosystem in the absence of artificial human disruptions." Common characteristics of ecosystem baselines are also discussed. The authors relate the role of natural areas to ecosystem analysis (including International Biome Programme studies) and to global environmental monitoring. These discussions acknowledge the argument that natural areas are not pristine, countering that "a somewhat unnatural baseline is probably better than no baseline at all." The authors recognize that all natural areas will not be used equally in ecosystem monitoring and research studies, but they present arguments for the importance for maintaining all areas, regardless of the amount of research use.

special sites, monitoring examples, natural areas, baseline monitoring.

623. Jensen, J. R.; Burkhalter, S. G.; Althausen, J. D.; Narumalani, S.; Mackey, H. E., Jr. 1993. **Integration of historical aerial photography and a geographic information system to evaluate the impact of human activities in a cypress-tupelo swamp**. Proceedings of the 14th biennial workshop on color aerial photography and videography for resource monitoring; 1993 May 25-29; Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 125-131.

Interpretations of 1:20,000 scale black and white aerial photographs taken in 1938, 1943, 1951, and 1973 and of 1:4500 scale color photographs taken in 1976, 1981, and 1986 were used to assess the effects of logging and thermal effluent on a 3800 acre swamp. Logging features were identified from the older photographs and converted to digital format in a geographic information database. The effects of thermal effluent was evaluated by interpreting timber loss and changes in plant communities as well as sediment deposition on the deltas using the 1:4500 scale photos. Based on these interpretations, only about a third of the swamp remains unaffected by human activity.

landscape-level, vegetation mapping, riparian, remote sensing, aerial photography, canopy cover, forest, disturbance, pattern, landscape change, wetland.

624. Jensen, M. E.; Hann, W.; Keane, R. E.; Caratii, J.; Bourgeron, P. S. 1994. **ECODATA--A multiresource database and analysis system for ecosystem description and evaluation**. In: Jensen, M. E.; Bourgeron, P. S., eds. Ecosystem Management: principles and applications. Gen. Tech. Rep. PNW-318. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 203-216.

monitoring examples, agency guidance and policy, ecological monitoring programs, landscape-level, ecosystem, ecosystem management.

625. Johannsen, C. J.; Saunders, J. L., eds. 1982. **Remote sensing for resource management**. Ankney, IA: Soil Conservation Society of America. 665 p.

remote sensing.

626. Johnson, D. H. 1981. **How to measure habitat-- a statistical perspective**. In: Capen, D. E., ed. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Experiment Station: 53-57.

design, analysis, statistics overview.

627. Johnson, F. A.; Hixon, H. J. 1952. **The most efficient size and shape of plot to use for cruising in old-growth douglas-fir timber**. Journal of Forestry. 50: 17-20.

tree, forest, inventory, plot dimensions, design.

628. Johnson, J. L., Franklin, J. F., Krebill, R. G., tech. coords. 1984. **Research natural areas: baseline monitoring and management**; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 84 p.

This volume contains the proceedings of a symposium on baseline monitoring and management in research natural areas.

special sites, monitoring examples, natural areas, monitoring overviews, baseline monitoring.

629. Johnson, J. R.; Schrumpf, B. J.; Mouat, D. A.; Pyott, W. T. 1974. **Inventory and monitoring of natural vegetation and related resources in an arid environment, an evaluation of ERTS-1 imagery**. Final Contract Rep. Type III, NASA Contract 5-21831. Greenbelt, MD: NASA Goddard Space Flight Center. 328 p.

landscape-level, rangeland, remote sensing, landscape change, large-scale monitoring.

630. Johnson, K. L. 1986. **Sagebrush over time: a photographic study of rangeland change.** In: McArthur, E. D.; Welch, B. L., comps. Proceedings-- symposium on the biology of *Artemisia* and *Chrysothamnus*; 1984 July 9-13; Provo, UT. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 223-252.

Twenty current photographs of landscapes were compared to the same scene photographed in the 1870s to determine changes in sagebrush stands. Those shown are the most useful out of 100 comparative photographs taken. The modern photographs were taken over 12 years. Field work to locate matches was noted as time-consuming, but no estimate of required expenditure was provided. The author attempted to duplicate the seasonality and light of the originals, which sometimes necessitated several trips.

field techniques, photopoints, The.

631. Johnson, M. 1994. **Changes in southwestern forests: stewardship implications**. Journal of Forestry. 92: 16-19.

By comparing two forest inventories completed 25 years apart, the author identifies a dramatic increase in mixed conifer forest types due to encroachment of shade tolerant conifers into other types such as aspen and ponderosa pine. Conifers have also invaded meadow areas. These changes are largely attributed to fire suppression and reduction of timber harvest. Additional references to early reports (late 1800s and early 1900s) provide support for the conclusion that forests have changed significantly since presettlement times. These changes leave the forest vulnerable to insect epidemics, dwarf mistletoe infestations, and high intensity wildfire. The author recommends aggressive management including harvest of small trees, intensive pre-commercial thinning, increased prescribed fire, salvage logging, and clearcutting of aspen stands to stimulate large blocks of regeneration.

landscape-level, agency guidance and policy, inventory, large-scale monitoring, forest, coniferous forest, deciduous forest, ecotones.

632. Johnson, M. K. 1986. **Estimating ratios of live and dead plant material in clipped plots**. Journal of Range Management. 39: 90-91.

Separating live and dead material to determine biomass or production can be a tedious task. In this study, known mixtures of live and dead material were assessed using microscope slides. Two slides containing the material were used for each mixture and 20 fields were analyzed for each slide. In each field, occurrence of live or dead material was noted. The process was repeated three times. Regression of known and estimated percent composition was highly correlated (r=0.98) with deviations from the known percentages less than 3.5%. Approximately 5 samples per hour can be analyzed using this approach.

field techniques, biomass, performance, production, weight estimate.

633. Johnson, R. 1993. **What does it all mean?** Environmental Management and Assessment. 26: 307-312.

Development of a program for water quality monitoring of forest practices involved several state and federal agencies, timber interests and environmental groups. A monitoring design that was satisfactory to all parties came with a $4 million implementation cost. The parties agreed to a year of qualitative monitoring by a team representing all interests. The approach was moderately effective, but the lack of quantitative data showing links between forest practices and their effect has raised additional political problems. The key lesson is that monitoring must have the confidence of all parties involved in order to be effective.

monitoring examples, monitoring overviews, monitoring and management, objectives, adaptive management, interdisciplinary design, aquatic, environmental monitoring programs.

634. Johnson, W. C.; Bratton, S. P. 1978. **Biological monitoring in UNESCO biosphere reserves with special reference to the great Smoky Mountain National Park**. Biological Conservation. 13: 105-115.

An approach to biological monitoring in UNESCO biosphere reserves is presented. The method is based on a sequence of steps involving prediction, monitoring, and assessment. The prediction step focuses effort on developing predictive models and formulating specific hypotheses of change. These predictions are tested in the second step, monitoring. In the assessment step, monitoring data are evaluated and interpreted. Using Great Smoky Mountains National Park as an example, the authors illustrate how this procedural sequence could be applied to ecological questions at local, park-wide, regional, and global scales. The examples presented for each scale emphasize the importance of articulating the purpose of monitoring. The authors also discuss how monitoring would be designed and implemented and how the results of monitoring would be applied to ecological management.

monitoring examples, scale, ecological monitoring programs, national parks, ecological models, special sites.

635. Johnston, A. 1957. **A comparison of line interception, vertical point quadrat and loop methods as used in measuring basal area of grassland vegetation**. Canadian Journal of Plant Science. 37: 34-42.

This study compared line intercept, point intercept, and loop methods in western wheatgrass stands (rhizomatous single stalked species). The loop method was the fastest but most variable. It also detected fewer species than the other two methods. Point intercept was the least variable and faster than line intercept. Line intercept, however, detected more species. With increasing vegetation complexity and density, field time for line intercept increased but point and loop intercept did not.

field techniques, technique comparison, basal area, line intercept, point intercept, loop frames, cover, grassland.

636. Jones, D. 1984. **Use, misuse and role of multiple comparison procedures in ecological and agricultural entomology**. Environmental Entomology. 13: 635-649.
analysis, multiple comparisons.

637. Jones, D.; Matloff, N. 1986. **Statistical hypothesis testing in biology: a contradiction in terms**. Journal of Economic Entomology. 79: 1156-1160.
analysis, statistical interpretation, precision, confidence intervals.

638. Jones, K. B. 1986. **The inventory and monitoring process**. In: Cooperider, A. Y.; Boyd, R. J.; Stuart, H. R., eds. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Department of Interior, Bureau of Land Management: 1-9.
monitoring overviews, inventory, objectives, adaptive management.

639. Jones, K. B.; Riddle, B. R. 1996. **Regional scale monitoring of biodiversity**. In: Szaro, R. C.; Johnson, D. W., eds. Biodiversity in managed landscapes. New York, NY: Oxford University Press: 193-209.

Monitoring is designed to measure change (difference between two time periods) or trend (trajectory based on three or more time periods). It can be either synoptic, such as landcover changes or trends over time measured from satellite imagery, or sample-based. Sample-based designs can be either representative, such as the sites chosen for the Long-term Ecological Research program (LTER), or probability based, such as the Environmental Monitoring and Assessment Project (EMAP). A monitoring program for biodiversity at the national scale should incorporate three levels: a regional scale detection level (assessment questions such as: what proportion of watersheds in Region X have natural cover types with decreasing patch size?); a diagnostic level which seeks to confirm problems and identify causes; and a cyclic incremental level at which the effects of management actions would be monitored. It will be necessary to identify indicators at the regional scale which are based on societal values of biodiversity. Criteria for indicators and several options are discussed. It will also be necessary to decide whether the indicators can be measured synoptically or by a sample-based design, and if the latter, whether the sample will be representative or probability based. Probability based sampling is preferred, but since stratification at regional levels may be difficult (or impossible) due to lack of knowledge or a reluctance to impose a classification on the sampling design, adequate sample size may be costly. Sample size will need to be estimated by conducting simulations and field tests of variability of the chosen indicator.

landscape-level, biodiversity, ecological monitoring programs, monitoring definitions, monitoring examples, adaptive management, feedback loops, monitoring and management, fragmentation, indicators, pattern, regional planning, scale, large-scale monitoring.

640. Jones, R. M.; Hargreaves, J. N. G. 1979. **Improvements to the dry-weight-rank method for measuring botanical composition**. Grass and Forage Science. 34: 181-189.
field techniques, production, dry-weight-rank, community composition, community-level.

641. Jongman, R. H.; TerBraak, C. J. F.; Van Tongeren, O. F. R., eds. 1995. **Data analysis in community and landscape ecology**. Wageningin, The Netherlands: Centre for Agricultural Publishing and Documentation. 299 p.

This book summarizes advances in community and landscape data analysis, and is the newest of the standard references on community multivariate analysis. A unique feature is a chapter on data collection, which in addition to the usual discussions on data types, sampling strategies, and distributions, points out several key problems in community research that are often ignored: 1) detection of pattern or correlation does not equal proof of a causal mechanism; 2) biased (non-random) sampling can cause misinterpretation; and 3) the need for assessment of power as well as significance in analyses. Techniques covered in this book are various types of regression analyses, ordination, clustering and classification, and spatial analysis with application to landscape level analyses. Chapters are written by different authors, and so differ in tone and approach, but for the most part, authors explain techniques in a textual form (supplemented with figures and examples), assuming that either a computer package will be used or additional information sought elsewhere.

landscape change, pattern, community composition, community structure, multivariate analysis, plant associations, vegetation mapping, landscape-level, community-level, statistics overview, analysis.

642. Jorgen, K.; Thomsen, K. 1994. **A new method for measuring tree height in tropical rain forest**. Journal of Vegetation Science. 5: 139-140.
heights, forest, tools, tree.

643. Jumars, P. A. 1980. **Rank correlation and concordance tests in community analysis: an inappropriate null hypothesis**. Ecology. 61: 1553-1554.

These tests, used to compare the rank orders of abundances of species between communities, may not be appropriate. Many of the commonly used nonparametric coefficients of correlation and concordance are based on the null hypothesis of a perfect evenness in the distribution of individuals in species rank order applications. This null hypothesis is inappropriate for most ecological communities in which most species are rare and a few are abundant. A community in which the species abundances are fairly even (e.g., 3 species with respective abundances of 0.35, 0.33, and 0.32) will have only a 0.01 probability of a sample containing the correct rank compared to the 0.55 probability for a community of three species with abundances of 0.70, 0.25, and 0.05. If the data are in the form of counts so that the relative abundances

are estimated, one can use the chi-square approximation for large samples, or the exact multinomial procedure for small sample sizes.

analysis, community-level, community composition, community change, species lists, multivariate analysis, nonparametric statistics, similarity measures.

644. Kaan, B. F.; Patterson, G. S. 1992. **Monitoring vegetation changes in conservation management of forests.** Forestry Commission Bulletin 108. 30 p.

tree, design, monitoring examples, forest, detecting change, monitoring overviews.

645. Kaiser, L. 1983. **Unbiased estimation in line-intercept sampling.** Biometrics. 39: 965-976.

field techniques, plotless methods, density, line intercept.

646. Kalkhan, M. A.; Stohlgren, T. J.; Coughenour, M. B. 1995. **An investigation of biodiversity and landscape-scale gap patterns using double sampling: a GIS approach.** Ninth annual symposium on geographic systems in natural resources management; 1995 March 27-30; Vancouver, British Columbia, Canada. 707-712.

In this paper the authors share a new approach to determining accuracy of remotely sensed geographic vegetation data. A double sampling technique combining aerial photography and ground data is being utilized and tested to determine the accuracy of LANDSAT thematic maps using Pielou's index of segregation, and to examine vascular plant species diversity at landscape scales. The study area includes Rocky Mountain National Park and adjacent lands. Three phases of work involved in conducting the double sampling for accuracy assessment are described in detail: 1) unbiased sampling of the landscape; 2) accuracy assessments using a composite estimator; and 3) use of GIS for accuracy assessments. Inventories of keystone ecosystems (e.g., meadows, riparian zones, etc.) are being conducted using high and low resolution photography (in nested grids ranging up to 1000m²), which yield data on vascular plant species composition and richness, percent cover, and species height. Although this work is in progress, the authors feel that double sampling appears to be a promising technique for obtaining unbiased estimates and increasing sampling efficiencies in assessing accuracy of thematic maps.

landscape-level, community-level, sampling design, design, remote sensing, aerial photography, pattern, national parks, vegetation mapping, GIS, TM, Landsat, species richness, canopy cover, heights, community composition.

647. Kalra, Y. P.; Maynard, D. G. 1991. **Methods manual for forest soil and plant analysis.** Ottawa, Canada: Minister of Supply and Services. 116 p.

vegetation sampling overview, soils.

648. Kalton, G.; Anderson, D. W. 1986. **Sampling rare populations.** Journal of The Royal Statistical Society Series A. 149: 65-82.

The emphasis and examples in this paper are on health surveys, but similar situations arise in ecology. Several methods are presented and illustrated with worked examples: screening (eliminating the units not of interest through a coarse filter before implementing more costly sampling), disproportionate sampling (higher sampling intensity in areas known to contain higher concentrations of the rare event), multiplicity sampling (add sampling units likely to contain the rare event because of some link, such as family relatives), and multiple frames (use of known occurrences of the rare event).

design, rare species, sampling design.

649. Karr, J. R. 1987. **Biological monitoring and environmental assessment: a conceptual framework.** Environmental Management. 11: 249-256.

This paper discusses application of the guild concept in biological monitoring and assessment. The author advocates use of ecological guilds for monitoring ecosystems, as opposed to individual indicator species. Utilization of a guild (ecological organization) approach in monitoring allows more flexibility in assessing impacts on ecological communities. Likewise, the author advocates monitoring based on a broad set of metrics and promotes an index of biotic integrity that he developed, which is based on 12 ecological characteristics. He illustrates his perspective with several examples, drawn largely from aquatic systems (invertebrates and fish) and bird communities.

monitoring examples, long-term ecological monitoring, indicators, functional groups, aquatic.

650. Kazda, M. 1995. **Changes in alder fens following a decrease in the ground water table: results of a geographical information system application.** Journal of Applied Ecology. 32: 100-110.

community-level, shrubland, shrub, GIS, community change, disturbance, wetland.

651. Keane, R. E.; Jensen, M. E.; Hann, W. J. 1990. **ECODATA and ECOPAC: analytical tools for integrated resource management.** The Compiler. 8(3): 24-37.

agency guidance and policy, monitoring examples, large-scale monitoring, environmental monitoring programs, long-term ecological monitoring.

652. Keddy, P. A. 1991. **Biological monitoring and ecological prediction: from nature reserve management to national state of the environment.** In: Goldsmith, F. B., ed. Monitoring for conservation and ecology. London: Chapman and Hall: 249-268.

community-level, landscape-level, ecosystem management, monitoring overviews, natural areas, baseline monitoring, monitoring examples, scale, predicting change, objectives.

653. Keith, L. H. 1990. **Environmental sampling: a summary.** Environmental Science and Technology. 24: 610-617.

Although this paper is written for environmental engineers concerned with sampling for pollutants, many of the recommendations are applicable to a vegetation monitoring project, and provide an interesting perspective. The author recognizes two types of environmental sampling: 1) surveillance, which is designed to provide preliminary information, and 2) monitoring, which is intended to provide information on the variation of a parameter over a period of time. Key design considerations in developing an environmental sampling project are data quality, quality control, documentation, sampling protocols (detailed directions), and sampling design.

integrated monitoring, field techniques.

654. Keith, L. H. 1992. **Principles of environmental sampling. A practical guide**. Chelsea, MI: Lewis Publishers. 143 p.

monitoring overviews, integrated monitoring.

655. Kelly, C. K. 1996. **Identifying plant functional types using floristic data bases: ecological correlates of plant range size**. Journal of Vegetation Science. 7: 417-424.

functional groups.

656. Kelly, J. R.; Harwell, M. A. 1990. **Indicators of ecosystem recovery**. Environmental Management. 14: 527-545.

Because we lack ecological understanding of the response of ecological systems to stress, and the form of the recovery for most types of stresses and ecosystems, there continues to be occurrences of both unexpected adverse effects from unregulated activities and unnecessary and expensive over-regulation of others. In characterizing ecosystem response to stress, no single spatial or temporal scale can be selected, thus the authors argue that it is unlikely that a "simplistic, generically applicable, single measure of ecosystem health" will ever be determined. A more productive strategy is to identify desirable endpoints that are of particular relevance to humans. One must then select from a suite of potential indicators of ecosystem change, recognizing that each reflects only some chosen facet of the system at some spatio-temporal scale. Five types of indicators can be recognized. Those of intrinsic importance are endpoints in and of themselves, and may include economic or endangered species. Early warning indicators are used when endpoints are delayed. Sensitive indicators are reliable for certain types of stress and recovery. Process indicators, such as decomposition rates, are used when the endpoint is an ecosystem function. Finally, one may wish to employ indicators of system sensitivity or vulnerability, such as the lack of nearby seed sources. Characteristics of indicators are also described: sensitivity to stress, rapid response, reliability of response, ease and economy of monitoring, relevance to endpoint, and potential for adaptive management.

objectives, scale, landscape-level, monitoring overviews, monitoring and management, disturbance, predicting change, objectives, indicators, ecosystem management.

657. Kelly, J. M.; Van Dyne, G. M.; Harris, W. F. 1974. **Comparison of three methods of assessing grassland productivity and biomass dynamics**. American Midland Naturalist. 92: 357-369.

field techniques, technique comparison, production, biomass, grassland.

658. Kemp, C. D.; Kemp, A. W. 1956. **The analysis of point quadrat data**. Australian Journal of Botany. 4: 167-174.

point intercept, cover, analysis, design, field techniques.

659. Kempton, R. A. 1979. **The structure of species abundance and the measurement of diversity**. Biometrics. 35: 307-321.

The author argues that theoretical standard errors for diversity values are usually incorrect because they are based on the assumption that repeated samples of fixed size are drawn from a homogeneous population. In reality, most natural populations are temporally and spatially heterogeneous.

community-level, analysis, precision, diversity indices, species diversity, species richness, precision, confidence intervals.

660. Kendall, R. H.; Sayn-Wittgenstein, L. 1960. **A rapid method of laying out circular plots**. Forestry Chronicle. 36: 230-233.

field techniques, sampling design, design, plot selection.

661. Kenkel, N. C.; Juhasz-Nagy, P.; Podani, J. 1989. **On sampling procedures in population and community ecology**. Vegetatio. 83: 195-207.

The authors point out that no single sampling design is optimal for all situations because the design is dependent on the objectives of the study. They identify several objectives. The sampling objective of parameter estimation is to maximize the precision of the sampled parameter (e.g., density, cover, number of flowers). The objective of pattern detection is to determine the spatial distribution and variation of entities. In univariate estimation, only a single parameter is considered, while in multivariate estimation, several to many variables are measured. Sampling design in situations where the objective is to measure units that are naturally recognized (e.g., number of seeds per pod) differs from that in which the sampling units are observer defined (e.g., quadrats, points). Considerations and recommendations for these typical ecological sampling situations are presented. Vegetation monitoring usually involves multivariate estimation in plots, and the authors recommend that for this situation a sampling design that minimizes the variances of species, and their covariances, will be optimal. A pilot study will be necessary to determine optimal plot size and shape.

design, community-level, analysis, plot dimensions, sampling design, community composition, covariance, objectives, multivariate analysis.

662. Kenkel, N. C.; Podani, J. 1991. **Plot size and estimation efficiency in plant community studies**. Journal of Vegetation Science. 2: 539-544.

The optimal plot size for estimation depends on the spatial distribution of the species of interest. In community studies, in which many species are of interest, it is possible that each species has a different distribution, and thus a different optimal plot size. The authors defined three efficiency criteria: 1) the sum of the variances for all species; 2) the variability of the species variances; and 3) a high compositional similarity between replicate plots, as measured by a low variance of eigenvalues. The authors sampled 3 different types of communities with square plot sizes ranging from $0.0625m^2$ to $9m^2$. Efficiency, as measured by the three criteria, improved with larger plot sizes, most dramatically with small increases in small plot sizes, less dramatically at the larger plot sizes. In general, the authors recommend that plot sizes be as large as possible, given the constraints on sampling effort (larger plots means fewer plots sampled). Plots somewhat larger than the mean patch size will likely provide the most efficient sampling design.

design, sampling design, community composition, plot dimensions, sample size, community-level, community change, community composition.

663. Kennedy, K. A.; Addison, P. A. 1987. **Some considerations for the use of visual estimates of plant cover in biomonitoring**. Journal of Ecology. 75: 151-157.

To determine error rates in the visual estimation of cover, the same observer re-estimated the cover in twenty 1x1m plots 9 times over 11 days. Errors associated with some species were over 20% of the mean cover (averaged over all plots). These were species with a large amount of wood compared to leaf area (like willows), plants with compound leaves, plants with creeping stems, and plants which were small or occurred only rarely (overlooked on some sampling occasions). Differences between successive samplings were smaller with later samplings, which the authors attributed to increasing familiarity and memory of individual plots and increasing familiarity with the vegetation. Initial samplings had several mis-identifications. Species with the highest mean cover values had the lowest rates of error. Authors also compared cover values over 5 months and over 4 years. May and September months were the most different from the others (June, July, and August). The authors attributed a 10% difference in cover to natural between-year fluctuations. The authors concluded that changes in vegetation cover would have to exceed 20% before a difference could be attributed to real biological change.

field techniques, cover classes, ocular estimation, cover classes, canopy cover, biological significance, observer variability, cover.

664. Kennedy, R. K. 1972. **The sickledrat: a circular quadrat modification useful in grassland studies**. Journal of Range Management. 25: 312-313.

An instrument is described that can be used on a circular quadrat 1m in diameter. The instrument revolves around the center of the quadrat via a staking system. A sickle on the forward edge of the instrument separates vegetation inside from that outside the plot, ensuring accurate boundary decisions for density counts or clipping.

field techniques, tools, density, biomass, production, grassland.

665. Kent, M.; Coker, P. D. 1992. **Vegetation description and analysis: a practical approach**. London: Belhaven Press. 363 p.

field techniques, vegetation sampling overview, analysis, multivariate analysis.

666. Kentula, M. E.; Brooks, R. P.; Gwin, S. E.; Holland, C. C.; Sherman, A. D.; Sifneos, J. C. 1993. **An approach to improving decision-making in wetland restoration and creation**. Boca Raton, FL: Lewis Publishers. 192 p.

The purpose of this book is to provide guidance on comparing natural and created wetlands to assess the success of meeting mitigation objectives. The first half of the book focuses on concepts and policies of wetland replacement programs and is not directly applicable to monitoring or comparison studies, although there are some concepts that may be useful in developing management objectives. Other chapters such as "Deciding on a sampling strategy," "Developing an efficient sampling strategy," "Suggested ways to represent the data collected" and "Techniques for determining differences in samples" are useful for any monitoring project. The book is written for managers, not academic ecologists or statisticians, and the techniques are relatively straightforward and standardized.

monitoring overviews, general examples, adaptive management, monitoring and management, objectives, analysis, graphical analysis, wetland.

667. Keough, M. J.; Quinn, G. P. 1991. **Causality and the choice of measurements for detecting human impacts in marine environments**. Australian Journal of Marine and Freshwater Research. 42: 539-554.

The choice of biological values or attributes to be measured is a crucial design component of monitoring. Some values are chosen because they are rare, high profile, of commercial importance, or of known indicator value. The choice of others can be guided by several ecological considerations: 1) Is there variation and is this variation correlated with human activity? 2) Is the relationship causal? 3) Is there a known or hypothesized mechanism underlying the relationship? and 4) What kind of sampling design is required to detect the changes? Measures can be made at the individual, population, or community level. Species diversity and/or richness is often used. These are popular because of the stability/diversity theories of the 1960s, the observed

local loss of species due to disturbance, and the current concern about biodiversity. Such approaches, however, are constrained by the expense of enumerating all species and the theoretical uncertainty about the relationship between disturbance and species richness or diversity. The authors provide an example of trampling in exposed rocky intertidal shore communities that demonstrates that univariate analysis of single species population response can often express relationships that are masked in community level analysis.

community-level, species lists, species richness, community composition, community change, indicators, species diversity, biological significance, objectives, landscape-level.

668. Keppel, G. 1982. **Design and analysis, a researcher's handbook. 2nd ed**. Englewood Cliffs, NJ: Prentice-Hall. 669 p.

This statistics text is designed for use in the behavioral sciences, but is also applicable to natural resource research. The difference between this book and some other statistical texts is that it explicitly combines experimental design with statistical testing. It also contains sections on repeated measures designs and power analysis. The latter is aided by an appendix of power curves, a rare addition to a statistics text. The book is not designed as an introduction to statistics--it is assumed that the reader has had at least a semester course. Information is presented on the level of a beginning graduate student. The style is more textual and intuitive than mathematical, but since the book was written before the widespread use of computers, the calculations required for each statistical test are presented. Examples are included to illustrate all techniques, and problems at the back of each chapter are answered in detail.

statistics overview, analysis, power, repeated measures analysis.

669. Kershaw, K. A. 1985. **Quantitative and dynamic plant ecology. 3rd ed.** London: Edward Arnold. 287 p.

This book provides an introduction to plant community ecology. Chapters include an introduction to statistical methods and sampling, succession, cyclic vegetation change, species associations and patterns, and multivariate ordination techniques.

statistics overview, vegetation sampling overview, multivariate analysis, succession, community change, community composition, analysis, community-level.

670. Kershaw, K. A. 1957. **The use of cover and frequency in the detection of pattern in plant communities**. Ecology. 38: 291-299.

community-level, community structure, pattern, cover, frequency, field techniques.

671. Kindschy, R. R. 1994. **Pristine vegetation of the Jordan Crater Kipukas: 1978-1991**. In: Monsen, S. B.; Kitchen, S. G., comps. Proceedings-- ecology and management of annual rangelands; 1992 May 18-21; Boise, ID. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 85-88.

Kipukas are isolated soil islands within a matrix of volcanic flow. The Jordan Crater Kipukas are two areas that are inaccessible except by arduous crossing of lavas, and thus are assumed to provide important ungrazed reference areas. Vegetation production was measured with clipped plots. Line intercepts were used to measure cover. Heights and classification to age class were completed on all sagebrush individuals occurring within belt plots and cryptogam cover measured with point intercepts. This design detected an increase in cheatgrass cover over 12 years from indiscernible to 10%.

special sites, community-level, annuals, field techniques, monitoring examples, reference areas, community composition, community change, rangeland, shrubland, canopy cover, line intercept, point intercept, production, heights, exotics.

672. King, T. J.; Woodell, S. R. J. 1987. **Problems in sampling desert shrub populations: a comment and a correction**. Journal of Ecology. 75: 201-202.

field techniques, cover, shrubland, shrub.

673. Kinsinger, F. E.; Eckert, R. E.; Currie, P. O. 1960. **A comparison of the interception, variable plot and loop methods as used to measure shrub-crown cover**. Journal of Range Management. 13: 17-21.

Measurements by three observers using line intercept (six 100ft transects), variable plots (6 points) and loop plots (3/4inch loop, 100 along each transect) were compared. Differences between observers were not significant for any of the methods. Dead crown cover was problematic, especially for the variable plot method which included dead portions of crowns and thus overestimated cover. Variable plots were also difficult to use when cover exceeded 20% because of the inability to differentiate individuals. Variable plots, however, were the most efficient; the 6 sampling units were adequate to estimate within 20% of the mean (95% confidence interval), while loop and line intercept required 14 to 104 sampling units for the same precision. Line intercept was the most accurate when compared to true cover. At cover values over 5%, the loop method gave an overestimate and was considered unreliable.

field techniques, cover, rangeland, shrub grassland, shrubland, canopy cover, line intercept, loop frames, variable plots, observer variability, technique comparison.

674. Kirby, K. J. 1988. **Woodland survey handbook**. Research and Survey in Nature Conservation 11. Peterborough: Nature Conservancy Council. 164 p.

tree, woodland, field techniques, general examples, vegetation sampling overview, inventory.

675. Kirmse, R. D.; Norton, B. E. 1985. **Comparison of the reference unit method and dimensional analysis methods**

for two large shrubby species in the Caatinga Woodlands. Journal of Range Management. 38: 425-428.
field techniques, production, cover, technique comparison, shrub, woodland, shrubland.

676. Kleiner, E. F. 1983. **Successional trends in an ungrazed, arid grassland over a decade.** Journal of Range Management. 36: 114-118.
special sites, community-level, community change, field techniques, succession, detecting change, grassland, general examples, point frames, cover, frequency, national parks.

677. Knapp, P. A.; Warren, P. L.; Hutchinson, C. F. 1990. **The use of large-scale aerial photography to inventory and monitor arid rangeland vegetation.** Journal of Environmental Management. 31: 29-38.
Using Organ Pipe Cactus National Monument as a study area, the authors demonstrate the use of large-scale color infrared and color aerial photography for making accurate photographic estimates of total perennial herbaceous, shrub, tree, and cactus cover. Nine test plots were selected for which 1975 aerial photography and vegetation data were available. Photo-interpretation using a dot grid method was conducted to measure vegetation cover change on aerial photographs from 1975 and 1983. The line intercept method was applied to 20x50m ground plots to verify photo data. In comparisons of photo and ground data, the authors found that both color infrared and color print photographs yielded accurate estimates of total vegetation cover and shrub cover. For trees and cacti, the color infrared photography yielded better estimates of cover compared to color print photographs.
remote sensing, landscape-level, special sites, general examples, aerial photography, canopy cover, national parks, long-term ecological monitoring, pattern, landscape change.

678. Knox, R. G.; Peet, R. K. 1989. **Bootstrapped ordination: a method for estimating sampling effects in indirect gradient analysis.** Vegetatio. 80: 153-165.
analysis, multivariate analysis, ordination, bootstrap, randomization tests.

679. Koch, C. F. 1987. **Prediction of sample size effects on the measured temporal and geographical distribution pattern of species.** Paleobiology. 13: 100.
design, sampling design, sample size.

680. Koch, G. K.; Amara, I. A.; Stokes, M. E.; Gillings, D. B. 1980. **Some views on parametric and non-parametric analysis for repeated measurements and selected bibliography.** International Statistical Review. 48: 249-265.
analysis, parametric statistics, nonparametric statistics, repeated measures analysis.

681. Koch, G. K.; Elashoff, J. D.; Amara, I. A. 1988. **Repeated measurements--design and analysis.** Encyclopedia of Statistical Sciences. 8: 46-73.
analysis, design, repeated measures analysis, sampling design, experimental design.

682. Kohl, M.; Innes, J. L.; Kaufmann, E. 1994. **Reliability of differing densities of sample grids used for the monitoring of forest condition in Europe.** Environmental Monitoring and Assessment. 29: 201-221.
sampling design, design, forest, tree, large-scale monitoring, monitoring examples, precision.

683. Kohl, M.; Schnellbacher, H. J.; Grunig, A. 1996. **Increasing spatial precision and accuracy for monitoring peatlands in Switzerland by remote sensing techniques.** In: Mowrer, H. T.; Czaplewski, R. L.; Hamre, R. H., eds. Spatial accuracy assessment in natural resources and environmental sciences: second international symposium; 1996 May 21-23; Ft. Collins, CO. Gen. Tech. Rep. RM-277. Ft. Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 441-450.
remote sensing, wetland, landscape-level, monitoring examples, large-scale monitoring, aerial photography.

684. Kolasa, J.; Pickett, S. T. A. 1991. **Ecological heterogeneity.** New York, NY: Springer-Verlag. 332 p.
sampling design, design, landscape-level, community-level, patch dynamics, scale, pattern.

685. Kondolf, G. M. 1995. **Five elements for effective evaluation of stream restoration.** Restoration Ecology. 3(2): 133-136.
monitoring overviews, aquatic, restoration.

686. Kooser, J. G.; Wilson, T. R. 1990. **A modified point-centered quarter sampling technique: a tool for plant community classification and evaluation.** In Mitchell, R. S., ed. Ecosystem management: rare species and significant habitats. New York State Museum Bull. 471. Albany, NY: New York State Museum: 57-60.
The authors describe a method of plant community evaluation that has been applied to Ohio's system of natural areas and preserves since 1982. It involves the following steps: 1) define plant community boundaries (sampling area); 2) select a random starting point and transect direction for a transect of 20 points; 3) measure distance to trees and tree diameter class at each point with the point-center quarter method; and 4) record all herbaceous and tree seedling species occurring in a 1x1m plot located near the point. To test the method, a 1.5ha area in each of three community types was completely surveyed for tree density and measured diameter (DBH). Similarity coefficients between actual values and sampled values were above 90% for experienced surveyors and generally above 80% for inexperienced surveyors. Most of the deviations in the inexperienced surveyors' results could be traced to incorrect DBH classification. In 5 of the 9 trials, inexperienced surveyors

produced mean DBH values significantly different than the actual values.

special sites, field techniques, density, community-level, forest, natural areas, community composition, community structure, species lists, deciduous forest, point-center methods, inventory, tree, ocular estimation, observer variability, monitoring examples, inventory.

687. Korning, J.; Thomsen, K.; Ollgaard, B. 1991. **Composition and structure of a species rich Amazonian rain forest obtained by two different sampling methods.** Nordic Journal of Botany. 11: 103-111.

community-level, community composition, community structure, design, sampling design.

688. Korning, J.; Thomsen, K. 1994. **A new method for measuring tree height in tropical rain forest.** Journal of Vegetation Science. 5: 139-140.

To measure tree height, three angles are measured with a clinometer from an unknown distance: base of the tree to the horizontal (angle C), the horizontal to the top of a pole of known height located at the base of the tree (angle B), and the angle formed by the horizontal to the top of the tree (angle A). The estimate is most accurate when the difference between angles B and C is large, thus accuracy can be improved by a long pole (6-7m is recommended).

field techniques, heights, tree.

689. Kothmann, M. M.; Waldrip, W. J.; Mathis, G. W. 1978. **Rangeland vegetation of the Texas rolling plains: response to grazing management and weather.** In: Hyder, D. N., ed. Proceeding of the 1st International Rangeland Congress; 1978; Denver, CO. Denver, CO: Society for Range Management: 606-609.

Vegetation frequency was sampled annually on permanent plots in exclosures from 1960 to 1969, and then every 2 or 3 years until 1973, using 240 point intercept frames (10 points per frame). Changes over time showed some response to grazing exclusion, but this was nearly swamped by the annual variation due to precipitation.

biological significance, community-level, field techniques, vegetation treatments, community change, succession, frequency, cover, point intercept, point frames, rangeland, natural variability, monitoring examples, long-term ecological monitoring, permanent plots.

690. Kraemer, H. C.; Theimann, S. 1987. **How many subjects? Statistical power analysis in research.** London: Sage.

analysis, sample size, power, Type I and Type II errors.

691. Krajewski, C. 1994. **Phylogenetic measures of biodiversity: a comparison and critique.** Biological Conservation. 69: 33-40.

landscape-level, biodiversity, species lists, species diversity, community-level.

692. Kratz, T. K.; Benson, B. J.; Blood, E. R.; Cunningham, G. L.; Dahlgren, R. A. 1991. **The influence of landscape position on temporal variability in four North American ecosystems.** American Naturalist. 138(2): 355-378.

landscape-level, ecological processes, natural variability, objectives.

693. Kratz, T. K.; Frost, T. M.; Magnuson, J. J. 1987. **Inferences from spatial and temporal variability in ecosystems: long-term zooplankton data from lakes.** American Naturalist. 129: 830-846.

long-term ecological monitoring, natural variability, biological significance, objectives.

694. Krebs, C. J. 1989. **Ecological methodology.** New York, NY: Harper and Row. 654 p.

This is one of the standard textbooks on ecological sampling. Much of the book is geared toward animal surveys, but the concepts of sampling design are germane to vegetation sampling as well. The book is not designed to describe field techniques, but rather stresses sampling design concepts such as the placement and size of sampling units. Most of the methods described are quadrat-based and point estimates of density--a chapter each on quadrats and distance methods. The middle section of the book is devoted to general concepts in sampling design such as sample size determination; sampling designs such as random, stratified, and multistage; sequential sampling; and experimental design. The third part of the book addresses community parameters such as similarity measures and species diversity indices.

design, analysis, field techniques, density, distance methods, sampling design, random sampling, stratified sampling, two-stage sampling, experimental design, density, similarity measures, clustering, precision, plot dimensions.

695. Kremen, C. 1992. **Assessing the indicator properties of species assemblages for natural areas monitoring.** Ecological Applications. 2: 203-217.

To test the usefulness of a suite of species for monitoring conditions in natural areas, patterns of butterfly diversity at two Madagascar forest sites were compared to environmental conditions, general topographic positions, plant diversity, floral diversity, and disturbance history (logging). Detrended and Canonical Correspondence Analysis (DCA, CCA) were used to explore the relationship of butterfly species patterns with environmental patterns. Statistical significance of explanation of an ordination axis by an environmental parameter was examined by Monte Carlo testing. Butterfly species patterns were good indicators of habitat heterogeneity due to a topographic/moisture gradient. Relationship to disturbance patterns was somewhat obscured by the strength of the topographic/moisture gradient, but when the data were analyzed based on groupings by that gradient, butterfly diversity provided good indication of disturbance in one type of habitat. Vegetation parameters were poorly predicted by butterfly assemblage patterns, and were themselves poor

indicators of the major environmental gradient. Because species assemblages will vary in their effectiveness for monitoring different ecosystem attributes or functions, it is critical to identify the goals of a monitoring program. Once these have been established, choice of indicators can be made in a two-step protocol: 1) test whether the assemblage is appropriate for indicating the ecological pattern of interest at the desired scale using indirect gradient analysis (such as DCA); and 2) test the significance of indicator properties using a direct gradient analysis technique such as CCA. Monitoring can use the entire assemblage of indicator organisms, or can focus on a selected subset with the strongest indicator value.

objectives, disturbance, indicators, community composition, community structure, community change, multivariate analysis, species lists, species diversity, community-level, disturbance, landscape-level, analysis, randomization tests, natural areas.

696. Krueger, W. C., chairman. 1985. **Symposium on the use of frequency and density for rangeland monitoring: Proceedings of the 38th annual meeting, Society for Range Management**; 1985 February; Salt Lake City, UT. Denver, CO: Society for Range Management.

field techniques, vegetation sampling overview, rangeland, frequency, density, general book on monitoring.

697. Kuehl, G. H.; Tueller, P. T.; Rowley, P. 1983. **Aircraft-borne radiometers for range vegetation assessment**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 402-405.

Radiometric data matching Landsat's Multispectral Scanner channels along with data from four narrow filter bands (centered at 475, 560, 690, and 785mm) were collected from a light aircraft at 300m. These data effectively identified different range condition areas delineated by ground sampling. The best correlation with range condition were two Landsat channels and two narrow filter bands.

landscape-level, community-level, pattern, community composition, vegetation mapping, rangeland, Landsat, MSS, remote sensing.

698. Kulow, D. L. 1966. **Comparison of forest sampling designs**. Journal of Forestry. 64: 469-474.

sampling design, design, forest, tree.

699. Kung, F. H.; Yang, Y. C. 1983. **Autoregression analysis of diameter growth**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 235-239.

Regression analysis of repeated measurements of tree growth trends with ordinary least squares is usually not appropriate because the residual errors are not independent. Autocorrelation of residuals can be checked by using the runs test or the Dubin-Watson test. In the presence of autocorrelation, a time series auto-regression model can be used to analyze the data.

analysis, repeated measures analysis, time series.

700. Kupper, L. L.; Haftner, K. B. 1989. **How appropriate are popular sample size formulas?** American Statistician. 43: 101-105.

Standard formulas for estimating the number of samples needed to achieve a desired statistical precision are based on large-sample approximations, and thus may underestimate the required number of samples in small-sample situations. This underestimation can be dramatic, increasing as the desired precision increases and the confidence interval narrows. This paper provides correction tables for the one-sample and two-sample situations. Standard formulas for minimum sample sizes to achieve a desired power were found to perform well, even for small sample sizes.

design, detecting change, precision, power, sample size.

701. Labau, V. J. 1993. **Regional monitoring with plot networks.** Environmental Monitoring and Assessment. 26: 283-294.

monitoring examples, large-scale monitoring, ecological monitoring programs, landscape-level, integrated monitoring.

702. LaBue, V. J. 1981. **An application of two-phased sampling methods for determining sample intensities in multiresource vegetation assessments**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 369-376.

design, community-level, integrated monitoring, sampling design, inventory, large-scale monitoring, community composition, aerial photography, remote sensing.

703. Lacaze, B.; Bebussche, G.; Jardel, J. 1983. **Monitoring changes and trends with Landsat and ancillary data: examples taken from Mediterranean lands**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 39-42.

Landsat data were useful for measuring acres in dryland agriculture planted annually, classifying rangeland into three condition classes, mapping fires, and monitoring vegetation regrowth. Accuracy of Landsat data was poor in predicting yields of agricultural areas.

rangeland, vegetation mapping, landscape-level, community-level, Landsat, remote sensing.

704. Laferriere, J. E. 1987. **A central location method for selecting random plots for vegetation surveys**. Vegetatio. 71: 75-77.

The preferred method for locating random plots is to divide the sampling area into a large number of sampling units, usually rectangular or square, from which a number of units can be randomly chosen and sampled. This is often difficult to implement in the field. An easier method is to chose plots based on distance and direction from a central location within the sampling area. But because the potential radii that can be chosen are closer together near the center of the plot, this method results in oversampling near the center. An alternative is to chose random rectangular coordinates, as in the first method, and then to calculate the distance and direction from the center of the sampling area. This paper describes a simple method for this approach, and a more complicated method for choosing coordinates and calculating distance and direction to sampling units for irregularly shaped polygons. No specifics are given, but an offer is made of two BASIC program listings or the programs on disk.

design, plot selection, random sampling.

705. Lake, P. A. 1986. **Symmetry, change, perturbation and observing mode in natural communities**. Ecology. 67: 223-239.

community-level, community change, detecting change, disturbance.

706. Lamacraft, R. R. 1978. **Observer errors in sampling ecological variables for range condition assessment**. In: Hyder, D. N., ed. Proceedings of the 1st International Rangeland Congress; 1978; Denver, CO. Denver, CO: Society for Range Management: 514-516.

Many field methods utilize some form of ocular estimation, such as cover estimates, condition estimates, and abundance estimates. These are subject to differences among observers. Observer errors can be of several types: heterogeneity of variance among observers, bias (consistent over- or under-estimation), nonlinearity (bias changes with the quantity observed), and unstable calibration (bias changes over time).

field techniques, cover, ocular estimation, observer variability.

707. Lamacraft, R. R.; Friedel, M. H.; Chewings, V. H. 1983. **Comparison of distance based density estimates for some rangeland vegetation**. Australian Journal of Ecology. 8: 181-187.

Known mapped communities of desert shrubs were used to test the effectiveness of several distance measures: nearest neighbor, point-center quarter, conditioned distance, and compound T-square. Samples were drawn from the population by both simple random and systematic sampling. All three populations were somewhat clustered. All distance measures underestimated the true density. The compound T-square was least affected by the spatial distribution of the plants, but the variance of estimates from this method increased with increasing contagion. In general, when plants are aggregated the random point to nearest neighbor distances underestimate density, while the individual to nearest neighbor distances overestimate density. The two sampling designs, random and systematic, produced similar results.

field techniques, technique comparison, distance methods, nearest neighbor, point-center methods, random pairs, angle-order, density, design, random sampling, systematic sampling, sampling design.

708. Landres, P. B. 1992. **Ecological indicators: panacea or liability?** In: McKenzie, D. H.; Hyatt, D. E.; McDonald, V. I., eds. Ecological indicators. Amsterdam: Elsevier Applied Scientific Publishers: 1295-1318.

Ecological indicators are used to assess population trends of other species, habitat quality, and ecosystem health. This paper discusses several problems with this approach: 1) detecting statistically significant change may be expensive, even when using indicators that are abundant and conspicuous; 2) there is no theoretical basis for assuming that increases in one species are positively correlated with that of other species; 3) density of the indicator species is not necessarily a good measure of habitat quality because of the complexity of habitat characteristics; 4) indicator species are often chosen because of their socioeconomic value, not because of their ecological value; and 5) managing for one species, the indicator, may actually be poor management for other species. Alternately, reference areas can be used to quantify the structural (species composition) and functional (production, nutrient cycling) components of a "healthy" ecosystem and to determine natural levels of variation and disturbance. Two types of indicators are needed: early warning indicators that signal a stress has occurred and diagnostic indicators that are sensitive to specific stresses. Some potential structural indicators include species composition, reproduction, richness, functionally dominant species, species size distribution, and guild structure. Functional indicators include production, production/biomass ratios, production/respiration ratios, decomposition rates, and nutrient cycling. Drawbacks remain even with an ecosystem approach to identifying indicators, primarily because of the lack of information about how structural and functional indicators interact with management, and the lack of a political framework (mandates, ecologically relevant administrative boundaries, and paucity of pristine or reference areas).

reference areas, special sites, landscape-level, community-level, agency guidance and policy, natural areas, biological significance, biodiversity, disturbance, ecological processes, ecosystem, ecosystem management, habitat management, indicators, regional planning, community composition, community structure.

709. Landres, P. B. 1995. **The role of ecological monitoring in managing wilderness**. Trends. 32(1): 10-13.

The author discusses the role of ecological monitoring in protecting and preserving wilderness character, criteria for choosing indicators to monitor, and emerging issues in wilderness monitoring. Criteria for choice of indicators include: ecological value, management impact and uncertainty, administrative needs and support, and external pressure. Emerging issues which are discussed include standardization of monitoring across all wilderness areas, and monitoring ecosystems.

special sites, monitoring examples, wilderness, objectives, monitoring overviews, ecological monitoring programs.

710. Landres, P. B. 1983. **Use of the guild concept in environmental impact assessment**. Environmental Management. 7: 393-398.

functional groups, landscape-level, adaptive management.

711. Landres, P.; Cole, D. N.; Watson, A. 1994. **A monitoring strategy for the national wilderness preservation system**. In: Hendee, J. C.; Martin, J. C., eds. International wilderness allocation, management, and research. Fort Collins, CO: International Wilderness Leadership Foundation: 192-197.

The authors present a conceptual model and strategy for developing a comprehensive and integrated program of monitoring for the National Wilderness Preservation System. The first part of the paper outlines three types of monitoring: 1) wilderness management monitoring; 2) wilderness reference monitoring; and 3) national system monitoring. The first type of monitoring is concerned with maintaining or improving wilderness values, and includes protection and use monitoring. Reference monitoring centers on utilizing Wilderness as a benchmark or comparison area for understanding ecosystems or management effects on non-Wilderness lands. National system monitoring is concerned with assessing status and trends in the Wilderness system. The second part of the paper describes a strategic process for bringing scientists and managers together in developing a unified Wilderness monitoring program.

objectives, monitoring examples, special sites, wilderness, ecological monitoring programs, integrated monitoring, interdisciplinary design.

712. Lang, G. E.; Knight, D. H.; Anderson, D. A. 1971. **Sampling the density of tree species with quadrats in a species rich tropical forest**. Forest Science. 17: 395-400.

field techniques, density, tree, forest, sampling design, design, plot dimensions, plot selection, precision.

713. Larson, F. R.; Mead, D. R. 1983. **Designing a comprehensive multi-resource field inventory for Alaska**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 313-317.

In this hierarchical inventory and monitoring method, Landsat is used to classify the landscape into basic units such as forest, herbaceous vegetation, and water. Aerial photography (1:6000 scale) is used to classify a subsample of the the Landsat units into general vegetation types. A subsample of these is given finer classification from 1:3000 scale aerial photos. Finally, a subsample of these are ground-truthed using a standard plot design to measure multiple values. Plots are a permanent 8ha cluster design in which 19 sampling points are arranged at 75m intervals. At each point, site type, overstory characteristics, tree tallies, and wildlife sign data is collected. Herbaceous vegetation is sampled at 5 points, down woody material at 2 points, shrub biomass at 4 points, detailed tree measurements at 9 points, and horizontal/vertical profiles at 4 points. The last measure is designed to measure vertical structure within a $100m^2$ horizontal area. Information is also collected on soils and wildlife observations. Each plot requires approximately 3 days for a team consisting of a forester, range or wildlife ecologist, and soil scientist.

design, monitoring examples, integrated monitoring, landscape-level, community-level, permanent plots, aerial photography, remote sensing, forest, pattern, community classification, vegetation mapping, community structure, community composition.

714. Larson, L. L.; Larson, P. A. 1987. **Use of microsite sampling to reduce inventory sample size**. Journal of Range Management. 40: 378-379.

Authors stratified grassland communities by drainage topographic position. Stratified random sampling reduced sample size requirements by 50-60%.

design, grassland, sampling design, sample size, stratified sampling.

715. Lauenroth, W. K.; Urban, D. L.; Coffin, D. P.; Parton, W. J.; Shugart, H. H.; Kirchner, T. B.; Smith, T. M. 1993. **Modelling vegetation structure-ecosystem process interactions across sites and ecosystems**. Ecological Modelling. 67: 49-80.

Eight Long-Term Ecological Research (LTER) sites (3 grasslands, 3 forests, and 2 transitional sites) are used to develop linked models of vegetation dynamics and ecosystem processes. The vegetation models are individual-based gap models which simulate establishment, growth, and mortality of individuals on an annual time-step. Since the scale of gaps and recruitment differ for forest systems compared to grasslands, a third model links the spatial scale of different life-forms, thus increasing the general applicability of the model, and allowing its use in transitional systems. Forest models emphasize light competition and simplify competition for water and nutrients. The grassland model emphasizes below ground competition. Dynamics in these models interact with compartment-based models of nutrients and soil water. Nutrients are modelled on a monthly time-step and water on a daily time-step. The models are still being tested and upgraded, but comparisons of model output over time

for the different sites appear to represent known trends well. The models are considered especially useful for predicting ecosystem change over time in response to large-scale perturbations, such as global warming.

monitoring examples, predicting change, long-term ecological monitoring, reference areas, ecological processes, ecological models, global change monitoring.

716. Lawton, J. H.; Jones, C. G. 1993. **Linking species and ecosystem perspectives**. Trends In Ecology and Evolution. 8: 311-313.

As disciplines, population ecology and ecosystem ecology must become linked in order to develop an integrated understanding of how the world works and meet societal demands on conservation biology. Much of the variation observed in ecosystem processes can be attributed to species-specific activities. For example, different species of trees and grasses have different impacts on mineralization rates in eastern deciduous forests and prairies. But the sheer number of species becomes unwieldy; thus, the challenge is to determine aggregations of species that allow for modelling of ecosystem processes while still incorporating critical features of individual species biology. Energy flow may provide a common currency, but most participants of the conference this article reviews felt that there was no universal currency or grand unifying theory. The issue of linking ecosystem and species is not academic. Contemporary social issues such as the spotted owl and "ecosystem health" both require ecosystem and population biology perspectives.

landscape-level, ecosystem, ecological processes, functional groups, indicators, rare species, ecosystem management.

717. Laycock, W. A. 1965. **Adaptation of distance measurements for range sampling**. Journal of Range Management. 18: 205-211.

The angle-order method (with supplementary measures of the individual plant weights and areas) was compared to weight estimate plots and line-intercept sampling to determine if it was useful for estimating density, production, and cover. For most species, the estimates of cover provided by the angle-order method were higher than the line-intercept. Two to twelve times as many angle-order points as 10m line-intercepts were required to sample cover with the same precision. Production was estimated 2 to 5 times higher for many species by the angle-order method compared to the weight estimate method. The angle-order method was found to provide relatively accurate estimates of density, production, and cover only if: 1) individual plants can be consistently recognized; 2) areas and weights of individual plants are measured very precisely; 3) more than one individual of each species is measured for weight and area at each point; and 4) species are evaluated separately. In communities with many species, the angle-order method was found to be too time-consuming. Two plot sizes for estimating herbage production ($96ft^2$ and $9.6ft^2$) were also compared. Visual estimates of herbage weight were considered more accurate on the smaller plot because the entire plot could be viewed at once, but more of the smaller plots were required to yield a given precision. No time comparisons were made.

field techniques, cover, density, production, community-level, community composition, rangeland, shrub grassland, distance methods, canopy cover, line intercept, weight estimate, angle-order, production, technique comparison, observer variability, precision.

718. Laycock, W. A. 1985. **Density as a method for monitoring rangeland vegetation**. In: Krueger, W. C., chairman. Symposium on the use of frequency and density for rangeland monitoring: Proceedings of the 38th annual meeting, Society for Range Management; 1985 February; Salt Lake City, UT. Denver, CO: Society for Range Management: 91-100.

community-level, field techniques, rangeland, community change, community composition, rangeland, density, distance methods.

719. Laycock, W. A.; Batcheler, C. L. 1975. **Comparison of distance-measurement techniques for sampling tussock grassland species in New Zealand**. Journal of Range Management. 28: 235-239.

Actual total counts within a 66x66ft sampling area of a tussock grass and a rosette species were compared to density estimated by 4 distance measures: closest individual, point-center quarter, angle order, and three variations of corrected point distance (Batcheler 1973). The tussock grass was found to be regularly dispersed on one site and aggregated on a second. The rosette was strongly aggregated. Closest individual and point-center quarter gave similar results, but overestimated density for the regularly dispersed grass and drastically underestimated density of the aggregated rosette (9% to 44% of true density). The angle order method gave estimates 33% - 52% higher than true density for the rosette species. The variations of corrected point distance all gave estimates within 20% of the mean; the most accurate was the method that measures point to nearest plant, then nearest plant to nearest neighbor, and then that plant to its nearest neighbor. The authors point out that not only do distance measures often give misleading results compared to true density, they are also poor measures of composition in community studies because the density for each species will vary depending on its spatial distribution.

field techniques, technique comparison, herbaceous species, grassland, distance methods, nearest neighbor, plotless methods, point-center methods, angle-order, density.

720. Leak, W. B. 1992. **Vegetation change as an index of forest environmental impact: considering a measure other than growth decline**. Journal of Forestry. 90: 32-35.

community-level, landscape-level, community composition, community change, landscape-level, landscape change, detecting change, design.

landscape-level, functional groups.*

721. Lee, P. M. 1989. **Bayesian statistics: an introduction**. New York, NY: Oxford University Press. 294 p.
analysis, Bayesian statistics, statistics overview.

722. Legendre, P. 1993. **Spatial autocorrelation: trouble or new paradigm?** Ecology. 74: 1659-1673.
analysis, design, sampling design, random sampling, experimental design.

723. Legendre, P.; Fortin, M. J. 1989. **Spatial pattern and ecological analysis**. Vegetatio. 80: 107-138.
Randomization tests (computer simulated sampling of random permutations of the data) were applied to multivariate data in the form of community censuses in order to test for community change.
community-level, analysis, community composition, community change, community comparisons, multivariate analysis, randomization tests.

724. Legendre, P.; Legendre, L., eds. 1987. **Developments in numerical ecology**. NATO ASI Series, volume G14. Berlin: Springer-Verlag. 585 p.
analysis, ordination, clustering, multivariate analysis.

725. Legendre, P.; Troussellier, M.; Jarry, V.; Fortin, M. J. 1989. **Design for simultaneous sampling of ecological variables: from concepts to numerical solutions**. Oikos. 55: 30-42.
The objective of the research described in this paper was to take pilot data for 10 variables from 63 sampling locations in a body of water and determine the optimal 20 sampling locations for more in-depth research. These 20 locations were intended to optimize the capture of variability, so as to best represent the body of water. Distribution maps created by kriging were constructed for each variable, and tested against the predictive power of the 20 chosen sampling points. Four methods were used to select the 20 locations. All began with clustering (with spatial contiguity constraint) of the initial sampling locations followed by: 1) clustering each variable separately to create 10 maps of homogeneous zones and then developing a single consensus map from the 10; 2) multivariate clustering (MC) into 20 groups, then selecting a station at random from among the clusters; 3) MC, then selecting the most central station; 4) MC, then selecting 20 stations, one from each group, that maximized the variance. While these methods are obviously analysis- intensive, all dramatically outperformed any random or systematic selection of 20 stations. The 4 approaches varied in their effectiveness at reproducing the different patterns shown by the 10 different variables.
design, pilot study, plot selection, clustering, multivariate analysis, sampling design.

726. Leishman, M. R.; Westoby, M. 1992. **Classifying plants into groups on the basis of associations of individual traits -- evidence from Australian semi-arid woodlands**. Journal of Ecology. 80: 417-424.

727. Leonard, G. H.; Clark, R. P. 1993. **Point quadrat versus video transect estimates of the cover of benthic red algae**. Marine Ecology Progress Series. 101: 203-208.
Underwater populations of algae were sampled with point and video methods. Point quadrats were sampled at 20 random locations in a 50x200cm sampling area. This area was also filmed, and the film sampled with 100 points. Five samples were filmed with natural and 8 with artificial light. More taxa were found with the point quadrat method; resolution of the video made species identification and detection of small species difficult. While analysis time was much higher for video transects (an additional 34.5 hours compared to point quadrats), video transects required half the people and half the time in the field compared to point quadrats.
field techniques, aquatic, canopy cover, cover, point intercept, photoplots, video, technique comparison.

728. Leps, J. 1987. **Vegetation dynamics in early old-field succession: a quantitative approach**. Vegetatio. 72: 95-102.
succession, grassland, community-level, community change, general examples.

729. Leps, J.; Hadicova, V. 1992. **How reliable are our vegetation analyses?** Journal of Vegetation Science. 3: 119-124.
The authors used two experienced observers to estimate cover within forty 5x5m plots using the Braun-Blanquet cover scale. Each plot was surveyed for 40 minutes. Discrepancies in species lists between the two observers was 13%. Average number of species found per plot by both authors combined was 18.3, but by each independently only 16.4. Most of the missed species were rare and small, with cover values of "trace" within the plots. In 57.5% of the estimations, the authors assigned the same cover value for species abundance; 39.5% of the observations differed by one class, and only 3% of the observations differed by more than one class.
field techniques, cover, canopy cover, releve, cover classes, species lists, observer variability.

730. Lesica, P. 1987. **A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects**. Natural Areas Journal. 7(2): 65-68.
field techniques, demographic techniques, rare species, permanent plots, detecting change.

731. Lesica, P.; Steele, B. M. 1996. **A method for monitoring long-term popoulation trends: an example using rare arctic-alpine plants**. Ecological Applications. 6(3): 879-887.
permanent plots, rare species, demographic techniques, density, alpine, arctic, long-term ecological monitoring, monitoring examples.

732. Levy, E. E.; Madden, E. A. 1933. **The point method of pasture analysis**. New Zealand Agricultural Journal. 46: 267-279.

field techniques, grassland, point intercept, cover.

733. Levy, P. S. 1977. **Optimum allocation in stratified random network sampling for estimating the prevalence of attributes in rare populations**. Journal of The American Statistical Association. 72: 758-768.

sampling design, design, random sampling, rare species.

734. Levy, P. S.; Lemeshow, S. 1991. **Sampling of populations: methods and applications**. New York, NY: Wiley and Sons. 420 p.

design, sampling design, sample size, random sampling, stratified sampling, systematic sampling, two-stage sampling.

735. Lewis, A. J. 1983. **Forest cover change detection using multiple data Landsat imagery**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 75-78.

Landsat imagery interpretation correctly identified and located clearcut boundaries 90% of the time. Cutting areas as small as two acres could be identified.

landscape-level, community-level, forest, tree, remote sensing, Landsat, community change, landscape change.

736. Lewis, T.; Taylor, L. R. 1967. **Introduction to experimental ecology, a student's guide to fieldwork and analysis**. London: Academic Press. 401 p.

analysis, field techniques, technique comparison.

737. Likens, G. E., ed. 1989. **Long-term studies in ecology**. New York, NY: Springer-Verlag. 214 p.

long-term ecological monitoring, monitoring examples, monitoring overviews.

738. Lillesand, T. M.; Klefer, R. W. 1994. **Remote sensing and image interpretation. 3rd ed**. New York, NY: Wiley. 768 p.

This is one of the newer textbooks available on remote sensing for resource management. Approximately 300 pages of the book are devoted to aerial photography, describing film types (including non-film media such as video recording and electronic imaging), filters, and scales. Current tools and techniques of interpretation are described, and a number of steroscopic pairs are included. The interpretation chapter also describes situations and uses in different fields such as water resources, range and forestry management, archaeology, and geology.

remote sensing, aerial photography, SPOT, AVHRR, Landsat.

739. Linden, D. S.; Rohde, W. G.; Bonner, K. G. 1981. **Estimating the area of vegetation types with Landsat and ancillary data**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 279-286.

Six approaches to the use of Landsat data are described: 1) manual interpretation of Landsat standard false-color or 2) enhanced false color composite images; 3) manually-interpreted vegetation type map used as a first level stratification for sample allocation; 4) computer classification used alone or as a first level stratification for sample allocation followed by 5) stratified cluster sampling or 6) two-stage stratified cluster sampling with double sampling. Accuracy and costs of the six approaches are compared for an area in northwestern Arizona.

landscape-level, community-level, vegetation mapping, pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, integrated monitoring, remote sensing.

740. Lindenmayer, D. B.; Nix, H. A. 1993. **Ecological principals for corridor design**. Conservation Biology. 7: 627-630.

This paper summarizes a study of marsupials and use of corridors in Australia. Use was primarily explained by habitat structure, the aspect of the corridor, its topographic position, the surrounding land use and the corridor's connectivity. Width, which varied among corridors by a factor of 10, was not found to be a significant explanatory variable. Species with colonial social structures and widely dispersed food sources were rarely found in corridors.

landscape-level, corridors, pattern, pattern, regional planning.

741. Lindsey, A. A. 1956. **Sampling methods and community attributes in forest ecology**. Forest Science. 2: 287-296.

design, sampling design, field techniques, community composition, forest.

742. Lindsey, A. A. 1955. **Testing the line-strip method against tallies in diverse forest types**. Ecology. 36: 485-495.

The line-strip method consists of sampling units 400x20ft in which tree density and total basal area by species is measured. Each tree is noted for its distance along the baseline, and measured for diameter (DBH). Canopy cover is measured, using the centerline of the strip as a line-intercept. A frequency value is also calculated, based on the occurrence of a species within subplots located contiguously along the line-strip. Frequency subplots are 50x20ft, but the authors point out that since the location of each tree along the baseline is known, frequency quadrats of any size can be defined as later office analysis dictates. In

this study, the estimates for density were compared to actual counts. Line-strip sampling units that covered about 10% of the area of the stands were highly efficient for sampling the density of dominant species. In a comparison of the percent standard error of the means for density, basal area and cover, the authors suggest that the 20ft width provides good balance of these errors (all approximately equal) in coniferous forest, while a slightly wider line (24ft) would provide better balance in deciduous forests. The 400x20ft plot design was less satisfactory for rare species; the authors suggested that lengthening the lines would improve the design. The alternate strip-quadrat method of Bormann (1953), in which subplots on alternate sides of a baseline are the sampling units, was also tested. Subplots were 50x20ft. These performed well for dominant species, but poorly for rare ones, and did not result in significant time savings.

design, tree, rare species, sampling design, plot dimensions, line intercept, cover, density, frequency, coniferous forest, deciduous forest, field techniques, DBH, basal area.

743. Lindsey, A. A.; Barton, Jr. J. D.; Miles, S. R. 1958. **Field efficiencies of forest sampling methods**. Ecology. 39: 428-444.

The following methods of measuring basal area and density were compared: six quadrat sizes and shapes (squares of 0.025ac, 0.1ac and 0.2ac, circles of 0.1ac, and 0.025ac, and a strip of 0.2ac), the point-center quarter method, the Bitterlich method, and the Bitterlich method modified with the addition of a plot for estimating density. Efficiency was defined in terms of field time needed to achieve the required level of precision in estimating density and basal area for two common species. The modified Bitterlich method was the most efficient, requiring only about 2 hours of field time. The next most efficient was the 0.1ac circular plot for one species and the Bitterlich method for a second; both required about 3 hours of field time. For both species, the smallest plots were the least efficient. In general, sampling units which could be measured from a single point were more efficient than square units which required marking, at a minimum, the plot corners. An efficient field approach was developed for each method and is described in sufficient detail to be applied.

deciduous forest, distance methods, point-center methods, variable plots, density, technique comparison, field techniques, basal area, plot dimensions, density.

744. Linthurst, R. A.; Thornton, K. W.; Jackson, L. E. 1992. **Integrated monitoring of ecological condition: issues of scale, complexity and future change**. In: McKenzie, D. H.; Hyatt, D. E.; McDonald, V. I., eds. Ecological indicators. Amsterdam: Elsevier Applied Scientific Publishers: 1421-1444.

The Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) is described. The program is designed to monitor and report the condition of the nation's ecological resources, and identify problems before they become widespread or irreversible. The monitoring is designed as four nested tiers. The first (Tier 1) is a baseline grid of about 12,600 points within the U.S. designed to estimate the extent of predefined resource classes. A portion of these points will be selected as Tier 2 sites for more detailed sampling on selected indicators. Sampling units selected for Tiers 3 and 4 will be monitored in successively more detail. The design is purposefully regional so effects and trends not obvious at local scales can be observed. The complexity of the regional and global systems will be addressed by using an epidemiological approach, in which the effects are monitored and causes are determined after a significant trend is observed. The program is design to identify change as it occurs. Developing a program that anticipated changes was considered difficult, if not impossible.

ecological monitoring programs, monitoring examples, long-term ecological monitoring, indicators, large-scale monitoring.

745. Lipsey, M. W. 1990. **Design sensitivity: statistical power for experimental research.** Newbury Park, CA: Sage Publications. 205 p.

The importance of statistical power is described for research in the behavioral sciences. The author's objective is to help researchers develop research designs that are sensitive and powerful enough to detect change or difference. This is obviously a critical issue for monitoring as well, because if monitoring shows there has been no significant change, it is important to know how large a change must occur before the monitoring design detects it. The book is short, readable, and contains a minimum of mathematical formulas. It provides a good introduction to concepts in power analysis for the interested but uninitiated reader.

design, analysis, detecting change, experimental design, power, sampling design, statistics overview.

746. Lodge, G. M.; Gleeson, A. C. 1979. **The effect of sample size and plot stratification on the precision of the wheel-point method of estimating botanical composition in clustered plant communities**. Australian Rangeland Journal. 1: 346-350.

community-level, community composition, rangeland, grassland, point intercept, field techniques, cover, design, sampling design, sample size.

747. Loeb, R. E. 1990. **Measurement of vegetation changes through time by resampling.** Bulletin of The Torrey Botanical Club. 117: 173-175.

The author identifies several sources of difficulty in resampling situations. One basic but potentially false assumption in resampling is the original data were accurately collected. A problem noted with permanent plots is selected areas representative at the first measure may no longer be representative at the second measurement. The most difficult resampling situation is when the original sample locations are not known. Differences between the two samples are then the

result of true changes over time and the error associated with sampling the vegetation. When only a single value is known for the earlier sample, the author suggests taking multiple modern samples. The significance of the change over time can be tested using a chi^2 test, with the expected value the average of the differences between the modern samples and the observed value the mean difference between the modern samples and the past one.

analysis, nonparametric statistics, long-term ecological monitoring, general examples, detecting change, observer variability, biological significance, precision, permanent plots.

748. Loeb, S. L.; Spacie, A. 1994. **Biological monitoring of aquatic systems**. Boca Raton, FL: Lewis Publishers. 400 p.

Using biological indicators is an established procedure in the monitoring of water quality. In summarizing these techniques, this book offers important insights and ideas for terrestrial vegetation monitoring as well. Some of the chapters are directly applicable: "Implementation of large-scale stream monitoring efforts: sampling design and data analysis issues," "Spatial and temporal variation in biological monitoring data" and "Landscape position, scaling and the spatial temporal variability of ecological parameters: considerations for biological monitoring." This book is especially useful for designing a monitoring project that encompasses a large area, or significant spatial or temporal variation.

design, landscape-level, community-level, objectives, natural variability, biodiversity, indicators, landscape change, scale, community composition, community change.

749. Loehle, C.; Gladden, J.; Smith, E. P. 1990. **An assessment methodology for successional systems. I. Null models and the regulatory framework**. Environmental Management. 14: 249-258.

monitoring and management, biological significance, ecological models, detecting change, community change, succession, community-level, objectives.

750. Loehle, C. J.; Smith, E. P. 1990. **An assessment methodology for successional systems. II. Statistical tests and specific examples**. Environmental Management. 14: 259-268.

community-level, community change, succession, monitoring and management, analysis, general examples, detecting change.

751. Londo, G. 1984. **The decimal scale for releves of permanent quadrats**. In: Knapp, R., ed. Sampling methods and taxon analysis in vegetation science. Handbook of vegetation science, volume 4. The Hague: Junk: 45-53.

field techniques, cover, herbaceous species, ocular estimation, multivariate analysis, permanent plots, cover classes, canopy cover.

752. Londo, G. 1974. **Successive mapping of dune slack vegetation**. Vegetatio. 29: 51-61.

charting, vegetation mapping, community-level, community change.

753. Long, B. G.; Dennis, D. M.; Skewes, T. D.; Poiner, I. R. 1996. **Detecting an environmental impact of dredging on seagrass beds with a BACIR sampling design**. Aquatic Botany. 53: 235-243.

This paper provides an example of the application of the Before/After/Control/Impact/Repeated measures (BACIR) sampling design to detect change .in an aquatic plant in response to dredging.

aquatic, detecting change, landscape-level, landscape change, design, BACI.

754. Long, G. A.; Poissonet, P. S.; Poissonet, J. A.; Daget, P. M.; Godron, M. P. 1972. **Improved needle point frame for exact line transects**. Journal of Range Management. 25: 228.

An improved needle point frame for use in dense herbaceous vegetation is described and illustrated. The frame is 2.4m long with 80 holes spaced 2.5cm apart. The needle is about 0.5mm diameter and 16mm long. It is moved along the frame with a sliding mechanism. The needle holder allows for slow downward movement and also contains a spring to return it to position after a reading. The instrument is cumbersome and delicate but provides very accurate and repeatable measures of point intercept.

field techniques, line intercept, canopy cover, point frames, point intercept, tools.

755. Lucas, H. A.; Seber, G. R. 1977. **Estimating coverage and particle density using the line intercept method**. Biometrika. 64: 618-622.

field techniques, line intercept, density, cover, analysis.

756. Ludwig, J. A.; Reynolds, J. F. 1988. **Statistical ecology**. New York, NY: Wiley-Interscience. 337 p.

This book focuses on ecological investigation that is inductive, nonexperimental, and multivariate. In this approach, community data consisting of species occurrence and abundances are collected, sometimes with accompanying environmental data, and the data are evaluated for biologically interesting patterns. Key tools are analysis of pattern (quadrat variance and distance techniques), diversity indices, species associations, classification, and ordination. The book is designed as an introduction to these techniques, and is well illustrated with ecological examples. Computer disks of programs used for analyses are included with the book.

community-level, analysis, community composition, multivariate analysis, diversity indices, species lists, plant associations.

757. Lund, H. G. 1992. **How to watch the forests. IUFRO guides for world forest monitoring**. Revista SELPER. 8(2): 40-44.

This paper reports on efforts of the Forest Resource Inventory and Monitoring Subject Group of the International Union of Forestry Research Organizations (IUFRO) to develop guidelines for global forest monitoring. The author reviews some of the many forest monitoring efforts currently underway and points out the lack of coordination and consistency between them. The overall goal of the guidelines being developed is to "promote internationally compatible data at the global level through national involvement." This includes promotion of an international network of permanent field plots, common remote sensing approaches, and accurate reporting of monitoring results. Also recommended is a minimum information set for all plots.

monitoring examples, global change monitoring, large-scale monitoring, permanent plots, remote sensing, integrated monitoring, detecting change.

758. Lund, H. G. 1978. **Multiple resource inventories in the United States**. Denver, CO: U.S. Department of Interior, Bureau of Land Management. 7 p.

Describes some of the integrated resource inventories implemented by resource agencies in the late 1970s. These may provide baseline data useful for monitoring projects.

general examples, inventory, integrated monitoring.

759. Luque, S. S.; Lathrop, R. G.; Bognar, J. A. 1994. **Temporal and spatial changes in an area of the New Jersey pine barrens landscape**. Landscape Ecology. 9: 287-300.

The New Jersey Pinelands National Reserve is designed to preserve the essential character of a 450,000ha area of the Pine Barrens landscape while providing for a range of human needs. Landscape level monitoring is needed to assess the direct impacts of suburban/exurban development, timber harvesting and fire protection on the frequency of wildfire, a critical ecological force in structuring the Pine Barrens landscape. This study assessed changes from 1972 to 1988 using Landsat Multispectral Scanner imagery and (for the last half of the study) Thematic Mapper data in an attempt to develop a method that would monitor landscape level changes. Five land cover classes were identified: mixed-deciduous forest, pine forest, non-forest (mostly human-altered areas), white cedar swamps, and water. About a third of the 223,000ha study area was outside the reserve. When compared with aerial photographs and vegetation maps, classification accuracy by Landsat data was nearly 90%. The method detected decreases in the size of continuous patches of forest within the reserve from an average of 333ha in 1972 to 168ha in 1988. Patch size outside the reserve showed similar patterns (54 to 24ha). Disturbances, measured by transitions from forested to non-forested cover classes, were 15% to 26% higher outside the protected area. Pine forest land cover presented a 72% retention frequency within the reserve compared to 44% outside. These comparisons suggest that management of the reserve is slowing but not eliminating the landscape change associated with increasing human use. The method was considered effective for monitoring the kinds of changes indicative of success or failure of management policies on landscape level patterns.

monitoring examples, national parks, natural areas, monitoring and management, wilderness, disturbance, ecological processes, fragmentation, habitat management, landscape planning, pattern, landscape change, pattern, regional planning, vegetation mapping, Landsat, MSS, TM, remote sensing, landscape-level, monitoring and management, special sites.

760. Lyon, J. G.; McCarthy, J., eds. 1995. **Wetland and environmental applications of GIS**. Boca Raton, FL: Lewis Publishers. 368 p.

Recent advances in Geographic Information Systems (GIS) and remote sensing are described and the application of the methods to landscape-level wetland management issues detailed. Of particular applicability to monitoring projects is a description of combining Landsat MSS and other data in a GIS system to determine changes in a urban riparian system and a large riverine wetland system.

GIS, Landsat, TM, MSS, remote sensing, riparian, landscape change, landscape-level, monitoring examples, wetland.

761. Lyon, L. J. 1968. **Estimating twig production of serviceberry from crown values**. Journal of Wildlife Management. 32: 115-119.

field techniques, shrub, crown diameter, canopy volume, production.

762. Lyon, L. J. 1968. **An evaluation of density sampling methods in a shrub community**. Journal of Range Management. 21: 16-20.

Nineteen methods of estimating density of shrubs were compared: 1) 8 quadrats of different dimensions (2x2ft, 5x5ft, 10x10ft, 20x20ft, 1x4ft, 2.5x10ft, 5x20ft, and 10x40ft); 2) 5 different length plots 6ft wide and long enough to capture one to five plants; 3) the point-center quarter method; 4) the angle method; 5) the angle order method; 6) Morisita's angle order method; 7) Catana's wandering quarter; and 8) the wandering angle. The area sampled was 8ac in size. All shrubs within this area were completely enumerated using 100x100ft grids. Of the tested sampling methods, only the squares, rectangles, and wandering quarter methods resulted in accurate density estimates (within 2 standard errors of the true value). None of the methods required less field time than the complete count to achieve means within ±50 plants per acre with a 95% confidence level. Nearly 18,000 squares of 2x2ft would be required to reach this precision. For the 20x20ft plot dimension, 213 plots would be required to reach this precision, comprising a search area of 1.96ac, nearly 25% of the total area.

shrub grassland, shrubland, density, distance methods, nearest neighbor, plotless methods, point-center methods, random pairs, wandering quarter, variable plots, technique comparison, density, angle-order, precision, field techniques.

763. MacBerthouex, P.; Brown, L. C. 1994. **Statistics for environmental engineers**. Boca Ratan, FL: Lewis Publishers. 352 p.

The design of the book is unusual among statistics texts in that each of the 40 chapters is centered around a case study, giving a description of the appropriate methodology, a worked example, and the strengths and weaknesses of the approach. Examples are from the field of environmental engineering and assessment, primarily for water quality (hazardous waste, regulatory requirements, pollutant monitoring). The plant ecologist will need to imagine vegetation-based situations that are similar to the case studies. In spite of this drawback, the unique structure of the book provides a valuable tool for understanding the application of statistics to real monitoring and inventory situations.

design, analysis, sampling design, statistics overview.

764. Macchiato, M. F.; Rogosta, M.; Cosmi, C.; Porto, A. L. 1992. **A method in multivariate statistics to analyze ecosystems starting from their species composition**. Ecological Modelling. 62: 295-310.

community-level, landscape-level, species lists, community composition, analysis, multivariate analysis, ecosystem.

765. MacDonald, A.; Armstrong, H. 1989. **Methods for monitoring heather cover**. Research and Survey in Nature Conservation 27. Peterborough: Nature Conservancy Council. 30 p.

shrubland, shrub, wetland, cover, field techniques, monitoring examples, wetland.

766. MacDonald, L. H.; Smart, A. 1993. **Beyond the guidelines: practical lessons for monitoring**. Environmental Monitoring and Assessment. 26: 203-218.

This article supplements MacDonald and others (1991). Based on implementation of the guidelines given in that publication and feedback from workshops, the authors identify several important points: 1) monitoring is a continuum from subjective observations to rigorous, statistically valid studies; 2) understanding the system is critical to identifying efficient measurement parameters; 3) identifying specific objectives is the most difficult and the most important part of the monitoring project; 4) peer review enhances success; 5) data management is often ignored, but critical; 6) monitoring results always have associated risks and uncertainties; 7) photos should always be included; 8) identification of scale and selection of monitoring sites must be explicitly addressed; 9) monitoring the management activity itself (implementation of standards) may be more effective than measuring its effects on the resource; and 10) a successful monitoring project usually has a committed individual or group.

monitoring overviews, monitoring examples, interdisciplinary design, sampling design, adaptive management, objectives, biological significance, monitoring and management, design.

767. MacDonald, L. H.; Smart, A. W.; Wissmar, R. C. 1991. **Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska.** EPA/910/9-91/001. Seattle, WA: U.S. Environmental Protection Agency. 166 p.

Although written for water quality monitoring, the first part, titled "Developing a monitoring project," contains useful guidance for any type of monitoring. Included are a general overview of monitoring, a flow chart of decisions that must be made when designing a monitoring project, and an excellent overview of statistical considerations in monitoring, including the setting of acceptable Type I and Type II error rates.

monitoring examples, design, sampling design, ecological monitoring programs, monitoring definitions, monitoring overviews, objectives, aquatic, Type I and Type II errors, precision, power.

768. Mack, A.; Gregg, W. P.; Bratton, S. P.; White, P. S. 1981. **A survey of ecological inventory, monitoring, and research in U.S. National Park Service Biosphere Reserves.** Research/Resources Management Rep. 49. Atlanta, GA: U.S. Department of Interior, National Park Service, Southeast Region. 23 p.

special sites, monitoring examples, national parks, monitoring overviews, agency plans, ecological monitoring programs.

769. Mack, R.; Pyke, D. A. 1979. **Mapping individual plants with a field portable digitizer**. Ecology. 60: 459-461.

charting, demographic techniques.

770. MacLean, C. D. 1981. **Walk-through inventory: a short-cut substitute for remeasuring slow-growing inventory plots**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 389-393.

tree, production, field techniques, inventory, permanent plots, density, DBH, basal area.

771. Madany, M. H.; West, N. E. 1984. **Vegetation of two relict mesas in Zion National Park**. Journal of Range Management. 37: 456-461.

This paper describes a study in which 12 permanent plots encompassing a range of vegetation types were established on two relict mesas within Zion National Park. Each 20x15m

macroplot was subjectively located in a homogeneous portion of vegetation. For each plot, elevation, slope, topographic position, bedrock, and soil type were measured and recorded. Vegetation variables included: 1) all tree stems greater than 5cm diameter (DBH) recorded by species and size class; 2) visual estimates of cover for saplings, shrubs, forbs, and graminoids within four 5x5m microplots; and 3) tree age. Photographs were also taken as part of the permanent documentation. Initial results and descriptions of vegetation are presented in the paper.

field techniques, design, special sites, permanent plots, forest, woodland, shrubland, cover, density, monitoring examples, national parks, photopoints.

772. Maeglin, R. M. 1979. **Increment cores: how to collect, handle, and use them**. Gen. Tech. Rep. FPL-25. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Lab. 18 p.

field techniques, tree-ring analysis.

773. Magee, T. K.; Antos, J. A. 1992. **Tree invasion into a mountain-top meadow in the Oregon Coast Range, USA**. Journal of Vegetation Science. 3: 485-494.

landscape-level, community-level, community change, tree, meadow, community structure, general examples.

774. Magill, A. W. 1989. **Monitoring environmental change with color slides**. Gen. Tech. Rep. PSW-117. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment Station. 55 p.

This illustrated guide was developed to guide land managers in monitoring human impacts on outdoor recreation sites and view landscapes utilizing repeat 35mm color slide photography. The methods could also be applied to monitoring ecological change. The author presents a series of repeat photographs of sites over periods of 9 to 26 years, with differing time intervals. Photographs are accompanied by detailed discussion to guide the reader in observing and analyzing changes. Examples of difficult situations and solutions are also presented. The publication concludes with a summary of recommendations for conducting repeat photography for monitoring.

field techniques, photopoints, permanent plots.

775. Magnuson, J. J. 1990. **The invisible present**. BioScience. 40: 495-501.

community-level, community change, succession.

776. Maguire, L. A. 1991. **Risk analysis for conservation biologists**. Conservation Biology. 5(1): 123-125.

Most managers and scientists are conservative, preferring mistakes or undesirable outcomes that stem from inaction to ones that result from intervention. Similarly in monitoring, Type I errors (claiming a change when one really hasn't taken place) may be considered, but Type II errors (missing a real change) is often ignored. The author recommends using a decision tree illustrating the potential outcomes and their consequences as a way to explicitly evaluate the risks involved in both management and monitoring activities in the face of lack of knowledge. This approach can be useful in deciding whether to implement management actions and whether monitoring should be more concerned with Type I or II errors.

design, objectives, monitoring and management, Type I and Type II errors.

777. Magurran, A. E. 1988. **Ecological diversity and its measurement**. Princeton, NJ: Princeton University Press. 179 p.

analysis, community-level, similarity measures, diversity indices, species richness, species diversity, community change.

778. Maki, A. W. 1980. **Methods issues in biological monitoring**. In Worf, D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D. C. Health and Company: 203-211.

Participants in a workshop on biomonitoring came to the conclusion that standardized methodology would lead to a loss of ecological meaning and relevance for many situations. Studies should be designed to meet particular objectives. The group did decide on the following criteria for indicator species: 1) ease of culture (if experiments will be done in the lab); 2) known and biologically meaningful response to known environmental situations and processes; and 3) widely distributed to potentially allow extrapolation to other locations.

design, indicators, objectives, ecological monitoring programs, monitoring overviews.

779. Malde, H. E. 1973. **Geologic bench marks by terrestrial photography**. U.S. Geological Survey Journal of Research. 1: 193-206.

field techniques, photopoints.

780. Malingreau, J. P. 1993. **Satellite monitoring of the world's forests: a review**. Unasylva. 44: 31-38.

This paper reviews current space-based earth observation technology and its application to forest monitoring needs. The author provides a brief good discussion on current and future application of remote sensors, including low-resolution (AVHRR), and high-resolution (Landsat MSS, TM, and SPOT). Three primary applications of remotely sensed forest data are also discussed: vegetation classification, detection of change in vegetation cover, and studying forest seasonality (tropical forests). The author concludes with recommendations for developing and implementing an effective global forest monitoring system.

landscape-level, general examples, landscape change, remote sensing, pattern, global change monitoring, GIS, Landsat, MSS, TM, AVHRR, forest, canopy cover, large-scale monitoring.

781. Mallows, C. L. 1979. **Robust methods--some examples of their use**. American Statistician. 33: 179-184.

Robust methods are those that have characteristics of resistance (insensitivity to the presence of a moderate number of bad values in the data and inadequacies of the assumed model), smoothness (gradual response to small perturbations in the data), and breadth. This paper summarizes some graphical techniques that are especially effective for dealing with large data sets such as climate data.

analysis, graphical analysis.

782. Manley, B. F. J. 1992. **The design and analysis of research studies**. New York, NY: Cambridge University Press. 353 p.

sampling design, experimental design, statistics overview, analysis.

783. Manley, B. F. J. 1991. **Randomization and Monte Carlo methods in biology**. New York, NY: Chapman and Hall. 281 p.

randomization tests, bootstrap, jackknife, analysis.

784. Mannetje, L. T.; Haydock, K. P. 1968. **The dry-weight-rank method for the botanical analysis of pasture**. Journal of The British Grassland Society. 18: 268-275.

field techniques, grassland, herbaceous species, community composition, production, dry-weight-rank, biomass.

785. Maquire, D. A. 1985. **The effect of sampling scale on the detection of interspecific patterns in a hemlock-hardwood forest herb stratum**. The American Midland Naturalist. 113: 138-145.

forest, herbaceous species, natural variability, scale, sampling design, design.

786. Màrcy, L. E. 1988. **Distance sampling techniques: section 6.2.2 of the U.S. Army Corps of Engineers wildlife resources management manual**. Tech. Rep. EL-88-23. Vicksburg, MS: U.S. Army Engineers Waterways Experiment Station. 38 p.

Three distance sampling techniques are discussed: point-center quarter, T-square nearest neighbor, and joint-point. Complete directions for field data collection, data sheets, and analysis calculations are given for each method. Time requirements for each sampling point of the point-center quarter method ranged from 1.5 to 31.5 minutes, with most vegetation types requiring 8 to 16 minutes per point. Wetland communities had the highest time requirements (23 to 31.5 minutes).

field techniques, density, wetland, distance methods, point-center methods, nearest neighbor, plotless methods.

787. Margules, C. R. 1992. **The Wog Wog habitat fragmentation experiment**. Environmental Conservation. 19: 316-325.

The paper describes the experimental design for a large-scale habitat fragmentation study in southeastern Australia. The experiment consists of 3 fragment sizes (0.25ha, 0.875ha, and 3.062ha), each with 2 controls (located in continuous native forest) and 4 treatment areas (located in an area cleared and planted to *Pinus radiata*). The main taxa evaluated are ground-dwelling arthropods and vascular plants.

landscape-level, general examples, disturbance, large-scale monitoring, experimental design, pattern, patch dynamics, fragmentation.

788. Margules, C. R.; Austin, M. P. 1994. **Biological models for monitoring species decline: the construction and use of data bases**. In: Lawton, J. H.; May, R. M., eds. Philosophical transactions: biological sciences: estimating extinction rates; 1994 April; London. Philosophical Transactions 344/1307. London: Royal Society of London: 69-75.

This paper describes recent advances in design and analysis of biological surveys to estimate more accurately spatial distribution patterns of species. The authors utilize a vegetation study in New South Wales, Australia to illustrate how to construct and use databases to analyze spatial relationships. The authors discuss and elaborate on attributes of compiling sound ecological databases including: 1) conceptual framework based on ecological theory; 2) field survey design principles and sampling locations based explicitly on the conceptual framework; 3) clear rationale for selecting the measurements made at sample sites; and 4) appropriate statistical methods for analyzing survey data and predicting distribution and abundance patterns from point sample data.

design, analysis, data management, sampling design, pattern, multivariate analysis.

789. Margules, C. R.; Austin, M. P., eds. 1991. **Nature conservation: cost-effective biological surveys and data analysis**. Canberra, Australia: CSIRO (Commonwealth Scientific and Industrial Research Organization). 207 p.

This book contains the proceedings from a 1988 workshop sponsored by the Australian Council of Nature Conservation Ministers and the Australian Environmental Council. The focus of the workshop and therefore the chapters in this book was to learn how to acquire biological survey data, and how to process the data into information needed for making land use decisions. The workshop explored ways to maximize the amount of useful information that could be obtained from surveys with limited funds, time, and personnel. The book is divided into six sections: "Costs and compromises," "Ecological theory and survey design," "Data collection and analysis," "Applications of survey results," "Case studies: lessons with the benefit of hindsight," and "Worked examples of data collection and analysis." (See annotations on individual chapters: Austin and Heyligers 1991; Austin 1991).

monitoring examples, inventory, analysis, design, general book on monitoring, large-scale monitoring, sampling design, data management, vegetation sampling overview.

790. Mario, G.; Sligman, N. 1996. **Long term plant community dynamics in a grazed Mediterranean grassland**. In: West, N. E., ed. Rangelands in a sustainable biosphere: Proceedings of the Fifth International Rangeland Congress; 1995 July 23-28; Salt Lake City, UT. Denver, CO: Society of Range Management: 193-194.

The effects of 4 grazing treatments on an annual and perennial grassland were studied by monitoring species cover for 20 years with point intercepts along permanent transects. Overall cover and percent composition varied widely from year to year. Dynamics appeared to be a mix of complex factors and interactions including vole outbreaks, weather conditions, demographic processes (such as high seed production) and grazing.

cover, point intercept, long-term ecological monitoring, natural variability.

791. Marion, J. L. 1991. **Developing a natural resource inventory and monitoring program for visitor impacts on recreation sites: a procedural manual**. Natural Resources Rep. NPS/NRVT/NRR-91/06. Washington, DC: U.S. Department of Interior, National Park Service. 59 p.

special sites, monitoring examples, inventory, national parks, protected areas.

792. Maritz, J. S.; Lwin, T. 1989. **Empirical Bayes methods**. London: Chapman and Hall. 284 p.

analysis, Bayesian statistics, statistics overview.

793. Mark, A. F.; Esler, A. E. 1970. **An assessment of the point-centered quarter method of plotless sampling in some New Zealand forests**. New Zealand Ecological Society Proceedings. 17: 106-110.

Complete tallies of trees and their diameters (DBH) were made on 1ac plots and the tally compared with that estimated by 50 point-center quarter (PCQ) sampling points. Seven different forest types were sampled. In most trials, PCQ underestimated density of small individuals and overestimated that of the larger size classes. Mean basal area estimates were consistently higher (7% to 46%) than the complete tallies.

field techniques, tree, DBH, community composition, coniferous forest, deciduous forest, density, distance methods, point-center methods, basal area, technique comparison, forest.

794. Markon, C. J. 1995. **History and use of remote sensing for conservation and management of federal lands in Alaska, USA**. Natural Areas Journal. 15(4): 329-338.

Because so little of Alaskan lands are accessible except by air, resource inventory is most practically done by remote sensing. This paper summarizes remote sensing analyses done to date in Alaska for natural resource inventory, providing a good summary and entry to the literature (over 80 references, including gray literature publications). Aerial photography has been used in Alaska for forest inventory, evaluation of oil pipeline construction on wildlife habitat (pre- and post-conditions), forest growth, habitat mapping, and wetland inventory. Vegetation successional trends after earthquake uplift is being monitored by 35mm aerial photographs of 2.9ha plots. Examples of use of Landsat and SPOT satellite data include vegetation mapping, caribou and reindeer habitat assessment and mapping, wetland mapping, land cover mapping, insect infestation, fire mapping, and seasonal vegetation analysis. Based on Landsat and SPOT data, a general land cover database now covers about 72% of the state. Additional coarse daily data from the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (AVHRR) are being used to document vegetation and landform changes twice each month.

landscape-level, remote sensing, Landsat, MSS, TM, pattern, landscape change, monitoring examples, AVHRR, aerial photography, inventory, vegetation mapping, habitat mapping.

795. Marrs, R. H.; Bravington, M.; Rawes, M. 1988. **Long-term vegetation change in the *Juncus squarrosus* grassland at Moor House NNR in northern England**. Vegetatio. 76: 179-187.

monitoring examples, long-term ecological monitoring, grassland, community-level, community change.

796. Marrs, R. H.; Raws, M.; Robinson, J. S.; Poppitt, S. D. 1986. **Long-term studies of vegetation change at Moor House National Nature Reserve: guide to recording methods and database.** Merlewood Research and Development Pap. 109. Grange over Sands, England: Institute of Terrestrial Ecology. 139 p.

monitoring examples, field techniques, long-term ecological monitoring, natural areas.

797. Martin, C. W.; Hornbeck, J. W. 1989. **Revegetation after strip cutting and block clearcutting in northern hardwoods: a 10-year history**. Res. Pap. NE-625. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station. 17 p.

long-term ecological monitoring, monitoring examples, detecting change, design, tree, forest, vegetation treatments, community-level, community change.

798. Maschinski, J.; Hammond, H. D.; Holter, L., tech. coords. 1996. **Southwestern rare and endangered plants. Proceedings of the second conference**. Gen. Tech. Rep. RM-283. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 328 p.

agency guidance and policy, monitoring examples, demographic techniques, rare species.

799. Matern, B. 1972. **The precision of basal area estimates**. Forestry Science. 18: 123-125.
field techniques, cover, basal area, point intercept.

800. Matloff, N. S. 1991. **Statistical hypothesis testing: problems and alternatives**. Environmental Entomology. 20: 1246-1250.

When testing whether a mean is statistically different from the value of the null hypothesis, the results can be misleading. In tests with large sample sizes, the test may demonstrate a significant p- value, but the difference between the two means is so small it is biologically irrelevant. Conversely, large differences may be identified as non-significant because of the small sample size or variability of the sample. The author recommends the use of confidence interval analysis, which estimates both the effect size (the difference of the measured value from the null value) and the precision of the estimate of that effect. An example of use of confidence intervals in two complex examples is presented.
statistical interpretation, confidence intervals, precision, biological significance, analysis.

801. Matson, P. A.; Carpenter, S. R. 1990. **Statistical analysis of ecological response to large-scale perturbations**. Ecology. 71: 2037-2068.
analysis, detecting change, design, landscape-level, disturbance, landscape change.

802. Mattson, D. E. 1981. **Statistics: difficult concepts, understandable explanations**. St. Louis: C. V. Mosby Company. 456 p.

This statistics book is designed for the mathematically fearful. Formulas, especially in the first half of the book, are kept to a minimum and concepts are explained with text and figures where possible. Over 100 pages are spent explaining introductory concepts of probability, sampling distributions, confidence intervals, and hypothesis testing. All chapters include exercises, and answers for all of these are included at the back of the book. The statistical tests described are limited to the more simple and often used: t-tests, chi^2, ANOVAs, correlation and regression, and nine nonparametric tests. Simple examples are numerous. This book will not likely meet the needs of someone with an intermediate knowledge of statistics because it does not provide the tools to deal with more complex situations, but it will appeal and be useful to the beginner.
analysis, statistics overview.

803. Max, T. A.; Schreuder, H. T.; Hazard, J. W.; Oswald, D. D.; Teply, J.; Alegria, J. 1996. **The Pacific Northwest Region vegetation and inventory monitoring system**. Res. Pap. PNW-493. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.
inventory, tree, forest, monitoring examples, large-scale monitoring, ecological monitoring programs.

804. Mayer, D. G.; Butler, D. G. 1993. **Statistical validation**. Ecological Modelling. 68: 21-32.
ecological models, time series, analysis, predicting change.

805. McAuliffe, J. 1990. **A rapid survey method for the estimation of density and cover in desert plant communities**. Journal of Vegetation Science. 1: 5-8.
field techniques, density, cover, rangeland, desert.

806. McBride, G. B.; Loftis, J. C.; Adkins, N. C. 1993. **What do significance tests really tell us about the environment?** Environmental Management. 17: 423-432.
statistical interpretation, analysis, biological significance.

807. McClanahan, T. R.; Muthiga, N. 1992. **Comparative sampling methods for subtidal epibenthic gastropods**. Journal of Experimental Marine Biology and Ecology. 164: 87-101.

Because many subtidal tropical animals are found at low population densities, traditional 1m^2 plots are of limited value in estimating their abundances (similar to problems in terrestrial plant sampling). An alternate method is search-sampling, which enumerates the number of individuals and species found in a certain search time. The problem with this method is variation among observer search ability, oversampling of large species, undersampling of common species due to habituation, and differences in sampling efficiency in different habitats, which limits the comparability of the data. In this study, one observer conducted three 60-minute search periods within a sampling area, utilizing a zig-zag pattern and limiting lingering in areas of high or low density. A second observer spent 5 to 10 minutes examining a randomly located 5m^2 quadrat. Number of quadrats per site ranged from 38 to 58. On half of the search-samples, a second less experienced observer also conducted a search. Quadrat sampling took from 1 to 4 hours longer than search sampling at each site. Some cryptic species were located by quadrat sampling and not search sampling, but at one site more species were found by search sampling. Similarity in species encountered between the 2 methods ranged from 67% to 89%. Abundance similarity was >85% for all sites except one with a high density of a single species. Coefficients of variation were higher for the quadrat sampling compared to search sampling. Population estimates for rare species measured by the quadrat method were unacceptable due to their variability and resulting high sampling error. There were no significant differences in population estimates measured by search sampling between the two observers. There was also no suggestion of habituation to common organisms or oversampling of large ones. The authors conclude that search sampling produced fairly reliable populations estimates, but suffers from the drawback that the data area in units of time spent searching rather than the preferred units of two-dimensional space.
community composition, species richness, species diversity, species lists, ocular estimation, sampling design, plot

dimensions, observer variability, technique comparison, field techniques, density, design, community-level.

808. Mcclendon, T.; Dahl, B. E. 1983. **A method for mapping vegetation utilizing multivariate statistical techniques**. Journal of Range Management. 36(4): 457-462.
community-level, vegetation mapping, multivariate analysis, analysis.

809. McCune, B. 1992. **Components of error in predictions of species compositional change**. Journal of Vegetation Science. 3: 27-34.
Differences between predicted species composition (generated, for example, from a succession model) and observed species composition can involve either rate of change, direction of change, or both. The author provides a technique for assessing the difference between predicted and observed changes in composition using a multivariate approach.
community-level, analysis, design, community composition, multivariate analysis, detecting change.

810. McDaniel, K. C.; Haas, R. H. 1982. **Assessing mesquite-grass vegetation condition from Landsat**. Photogrammetric Engineering and Remote Sensing. 48: 441-450.
remote sensing, grassland, shrubland, community change, Landsat, community-level, landscape-level.

811. McDaniel, K. C.; Haas, R. H. 1981. **Classifying and characterizing natural vegetation on a regional basis with Landsat MSS data**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 197-203.
landscape-level, general examples, pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, remote sensing.

812. McDonald, L. L. 1980. **Line intercept for attributes other than coverage and density**. Journal of Wildlife Management. 44: 530-533.
field techniques, cover, density, line intercept.

813. McDowall, D.; McCleary, R.; Meidinger, E. E.; Hay, R. A. 1980. **Interrupted time series analysis**. Beverly Hills, CA: Sage Publications. 96 p.
analysis, time series.

814. McGowan, J. A. 1990. **Climate and change in oceanic systems: the value of time series data**. Trends In Ecology and Evolution. 5: 293-299.
analysis, time series, natural variability.

815. Mcgraw, J. F.; Tueller, P. T. 1983. **Landsat computer-aided analysis techniques for range vegetation mapping**. Journal of Range Management. 36(5): 627-631.
community-level, inventory, remote sensing, Landsat, GIS, vegetation mapping, rangeland, shrubland.

816. McIntyre, G. A. 1953. **Estimation of plant density using line transects**. Journal of Ecology. 41: 319-330.
The line intercept method is usually used for measuring plant cover, but it can also be used for density measures. Density can be estimated based on the chord length of the intercept through each individual, but the estimate is increasingly biased as plant shape departs from circular. For plants with irregular outlines, the method is inappropriate. The author suggests that a more practical method for estimating density is to use strip quadrats in conjunction with line intercepts. For plants with fairly regular shapes, the chord method can be used if supplemented with subsample information on the longest chords parallel to the transect.
field techniques, density, line intercept.

817. McIntyre, G. A. 1952. **A method for unbiased selective sampling, using ranked sets**. Journal of Agricultural Research. 3: 385-390.
sampling design, design, plot selection.

818. McKell, C.; Bonham, C. D.; Goodin, J. R.; Gross, D. R.; Poulton, C. E.; Snedaker, S. 1983. **Plants**. In: Conant F.; Rogers P.; Baumgardner M.; McKell C. M.; Dasmann R.; Reining P., eds. Resource inventory and baseline study methods for developing countries. American Association Advisory Science Publication 83-3. Washington, DC: American Association for the Advancement of Science: 309-408.
This chapter provides guidance on plant resource inventories and baseline studies appropriate for use in developing countries. The chapter includes several sections: 1) plant ecology and resource use; 2) project planning, including setting objectives and identifying information needs; 3) uses of remote sensing; 4) field methods; 5) laboratory methods; 6) determination of indigenous use of plants; and 7) classification. Field methods include cover techniques (ocular estimates, belt transects, line intercepts, point intercepts, and loop methods), quadrat and plotless methods of density measurement, and biomass sampling. The chapter includes over 250 references, some arranged by sampling technique.
vegetation sampling overview, general book on monitoring, objectives, community composition, community structure, density, distance methods, canopy cover, cover classes, line intercept, loop frames, ocular estimation, point frames, point intercept, frequency, biomass, aerial photography, Landsat, remote sensing, field techniques, cover, density, frequency.

819. McLaughlin, S. P. 1978. **Determining understory production in southwestern ponderosa pine forests**. Bulletin of the Torrey Botanical Club. 105(3): 224.

field techniques, herbaceous species, forest, coniferous forest, production.

820. McLeod, A. I.; Hipel, K. W.; Camacho, F. 1983. **Trend assessment of water quality time series**. Water Resources Bulletin. 19: 537-541.
analysis, time series.

821. McLeod, R. G.; Johnson, H. B. 1981. **Resources inventory techniques used in the California desert conservation area**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 20-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 260-272.

The paper describes a hierarchical inventory system using Landsat data, aerial photography, digital terrain information, management and ownership areas, low-level aerial photography of ground transects, and actual ground data.
landscape-level, monitoring examples, pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, aerial photography, integrated monitoring, remote sensing.

822. McNeill, L.; Kelly, R. D.; Barnes, D. L. 1977. **The use of quadrat and plotless methods in the analysis of the tree and shrub component of woodland vegetation**. Proceedings of The Grassland Society of Southern Africa. 12: 109-113.

In a comparison of density estimation using quadrats and 8 distance measures in a sampling area in which all individuals had been mapped, the quadrats were found superior in all respects. Even quadrats, however, required a large sample size covering approximately 15% of the total area to reach a precision of ±20% of the mean with a 95% confidence level (quadrats were 5x5m).
field techniques, density, technique comparison, distance methods, plotless methods, shrub, tree, woodland, shrubland, nearest neighbor, random pairs, wandering quarter, angle-order, point-center methods.

823. McRoberts, R. E.; Hahn, J. T.; Hefty, G. J.; VanCleve, J. R. 1994. **Variation in forest inventory field measurements**. Canadian Journal of Forest Research. 24: 1766-1770.

Eight field crews independently measured one forest inventory plot, and 9 field crews a second for a total of 61 trees measured for diameter (DBH) and crown ratio. Diameter was measured to the nearest 0.25cm. Crown ratio was visually estimated as the ratio of the living crown to tree height to the nearest 10%. Outliers were identified as mistakes; means and standard deviations of the remaining measures were calculated. Diameter measures were generally within 0.75cm, with a coefficient of variation between individual estimates and tree means of less than 5%. Incidence of mistakes was 1.78%, with magnitudes of 1.78 to 38.86cm (-0.8% to 1.25% of tree diameter). For crown ratio, 87% of the estimates were within 10% of the mode, but estimates ranged to within 30% of the mode. The coefficient of variation between individual estimates and tree means was 73%.
ocular estimation, observer variability, tree, DBH, crown diameter, field techniques, basal area, inventory.

824. Mead, R. 1988. **The design of experiments: statistical principles for practical application**. New York, NY: Cambridge University Press. 620 p.
analysis, design, statistics overview, sampling design, experimental design.

825. Meese, R. J.; Tomich, P. A. 1992. **Dots on the rocks: a comparison of percent cover estimation methods**. Journal of Experimental Marine Biology and Ecology. 165: 59-73.

Visual estimation of cover, electronic digitizing of photographs, and 3 forms of point frames (systematic points, random points and stratified random points painted as dots on a clear sheet of plastic) were measured in ten 25x25cm plots in an intertidal area and compared for sensitivity and repeatability among observers. Variability between observers for visual estimation was highest for common species, a difference of nearly 15% cover. Digitized photographs showed the least difference between observers. Point frames tended to miss rare species, and had fairly high variability between observers (there was no effort to place frames the same way over each plot, and there was potential for observer bias in determining which species the points were actually above). Although the authors recommend photographic frames they recognize three potential problems: 1) film may be incorrectly exposed; 2) species may be difficult to identify on a photograph; and 3) only the topmost layer can be measured.
field techniques, cover, point intercept, ocular estimation, cover classes, canopy cover, photoplots, technique comparison, point frames, tools, observer variability.

826. Meeuwig, R. O. 1981. **Point sampling for shrub biomass**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 323-326.

Point intercept transects and variable plots were compared to $1m^2$ plots for estimating shrub production on macroplots where production was known. Both point methods were quicker and more accurate than the plots.
field techniques, cover, technique comparison, canopy volume, production, canopy cover, plotless methods, point intercept, variable plots, shrub grassland, shrubland.

827. Meeuwig, R. A.; Budy, J. D. 1981. **Point and line-intersect sampling in pinyon-juniper woodlands**. Gen.

Tech. Rep. INT-104. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 38 p.
field techniques, point intercept, line intercept, cover, technique comparison, woodland.

828. Menges, E. S. 1990. **Population viability analysis for an endangered plant**. Conservation Biology. 4(1): 52-62.
rare species, demographic techniques.

829. Menges, E. S. 1986. **Predicting the future of rare plant populations: demographic monitoring and modelling**. Natural Areas Journal. 6(3): 13-25.
rare species, demographic techniques.

830. Menges, E. S.; Abrahamson, W. G.; Givens, K. T.; Gallo, N. P.; Layne, J. N. 1993. **Twenty years of vegetation change in five long-unburned Florida plant communities**. Journal of Vegetation Science. 4: 375-386.
community-level, long-term ecological monitoring, community change, detecting change, succession, permanent plots, cover, forest, monitoring examples.

831. Mentis, M. T. 1981. **Evaluation of the wheel point and step point methods of veld condition assessment**. Proceedings of The Grassland Society of Southern Africa. 16: 89-94.
grassland, herbaceous species, point intercept, cover, field techniques, technique comparison.

832. Mentis, M. T.; Collinson, R. F. H.; Wright, M. G. 1980. **The precision of assessing components of the condition of moist tall grassveld**. Proceedings of The Grassland Society of Southern Africa. 15: 43-46.
field techniques, cover, design, precision, grassland, cover, community composition.

833. Merigliano, L. 1987. **The identification and evaluation of indicators to monitor wilderness conditions**. Moscow, ID: University of Idaho. 273 p. Thesis.
wilderness, special sites, monitoring examples, indicators, long-term ecological monitoring, large-scale monitoring.

834. Merigliano, L.; Krumpe, E. E. 1991. **The identification and evaluation of indicators to monitor wilderness conditions: report to participants of a Delphi study**. Report. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences. 33 p.
wilderness, special sites, monitoring examples, indicators, long-term ecological monitoring, large-scale monitoring.

835. Merrill, E. H.; Bramble-Brodahl, M. K.; Marrs, R. W.; Boyce, M. S. 1993. **Estimation of green herbaceous phytomass from Landsat MSS data in Yellowstone National Park**. Journal of Range Management. 46(2): 151-157.
special sites, Landsat, MSS, production, national parks, remote sensing.

836. Mertaugh, P. A. 1996. **The statistical evaluation of ecological indicators**. Ecological Applications. 6(1): 132-139.
indicators, detecting change, analysis.

837. Mesavage, C.; Grosenbaugh, L. R. 1956. **Efficiency of several cruising designs on small tracts in north Arkansas**. Journal of Forestry. 54: 569-576.
sampling design, inventory, design, tree, deciduous forest.

838. Messer, J.; Linthurst, R.; Overton, W. S. 1991. **An EPA program for monitoring ecological status and trends**. Environmental Monitoring and Assessment. 17: 67-78.
Introduces the Environmental Protection Agency's Environmental Monitoring and Assessment (EMAP) program.
monitoring examples, ecological monitoring programs, large-scale monitoring, long-term ecological monitoring.

839. Meurk, C. D. 1989. **Vegetation monitoring, with special reference to the subantarctic islands of New Zealand**. In: Craig, B., ed. Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on protected natural areas; 1988 May; Dunedin. Wellington: Department of Conservation: 209-219.
Vegetation monitoring is defined here as the "periodic assessment of individual 'tagged' (relocatable) communities, guilds, plants or ramets." Its purpose is to detect environmental change, determine the effects of management actions, and ultimately to provide direction for resource management. The author focuses on two approaches to permanent, relocatable monitoring: pictorial records and permanent quadrats. Photographs must be annotated and contain foreground and background features to allow relocation. Pictures should be taken at the same time of year and with the same equipment to control for seasonal and focal length variation. Permanent quadrats should be sized relative to the scale of the vegetation; suggested sizes for tall grassland or shrubland are 0.5 to 4m² quadrats or belts of 5 to 10 contiguous 0.25 to 1m² plots. Nested quadrats are recommended for forest types. Quadrats should be randomly established within strata of homogeneous communities. The author suggests that efficient monitoring focuses on a few important species rather than attempting to measure them all. In additional to general guidance, this paper provides a case study of monitoring the effects of sheep grazing on a sub Antarctic island. The study was designed around a single treatment (grazed) and control area (ungrazed). Vegetation was sampled in 325 quadrats (4.2x2m) along two 1.4km transects on either side of a dividing fence. These plots were stratified based on 5 vegetation types. Chi² tests and a one-way ANOVA were used to analyze the data. The results show dramatic recovery of native species in the ungrazed area.

monitoring definitions, monitoring overviews, monitoring and management, adaptive management, community composition, grassland, permanent plots, stratified sampling, analysis, monitoring examples, plot dimensions, sampling design, objectives, arctic, community change, community-level, design, detecting change, photopoints.

840. Michaelsen, J.; Schimel, D. S.; Friedl, M. A.; Davis, F. W.; Dubayah, R. C. 1994. **Regression tree analysis of satellite and terrain data to guide vegetation sampling surveys**. Journal of Vegetation Science. 5: 673-686.
landscape-level, design, remote sensing, inventory.

841. Millard, S. P. 1987. **Environmental monitoring, statistics and the law: room for improvement**. American Statistician. 41: 249-259.
The author notes that most monitoring requires careful statistical design in order to be within desired Type I and Type II error rates and to produce credible results and analyses, but statisticians are rarely involved in the design, and often not even involved in the analysis phase. Conversely, other fields such as the medical and pharmaceutical fields have long worked closely with and employed statisticians. The author cites three environmental monitoring studies that demonstrate common poor statistical design and the failure of monitoring to meet health protection objectives: a power company study on the effects of a project on aquatic organisms in a bay, the comparison of chemical concentration in soils of areas around Love Canal and control areas, and the detection of contaminants in standard groundwater testing.
design, analysis, detecting change, experimental design, power, precision, sampling design, Type I and Type II errors, analysis, statistical interpretation.

842. Millard, S. P.; Lettenmaier, D. P. 1986. **Optimal design of biological sampling programs using analysis of variance**. Estuarine, Coastal and Shelf Science. 22: 637-656.
ANOVA, analysis, sampling design, power, precision.

843. Millard, S. P.; Yearsley, J. R.; Lettenmaier, D. P. 1985. **Space-time correlation and its effects on methods for detecting aquatic ecological change**. Canadian Journal of Fisheries and Aquatic Sciences. 42: 1391-1400.
aquatic, community change, community-level, natural variability, detecting change, analysis.

844. Miller, R. I., ed. 1994. **Mapping the diversity of nature**. New York, NY: Chapman and Hall. 218 p.
Chapters include: "Baselines for resource development;" "Remote sensing assessment of tropical habitat availability;" "Mapping the global distributions of species;" and "A continental monitoring program."
monitoring examples, landscape-level, vegetation mapping, GIS, remote sensing, Landsat, MSS, large-scale monitoring, landscape planning, pattern.

845. Miller, R. I.; Wiegert, R. G. 1989. **Documenting completeness, species-area relations and the species-abundance distribution of a regional flora**. Ecology. 70: 16-22.
species lists, community-level, landscape-level.

846. Miller, W. A.; Moore, D. G. 1983. **Time-series vegetation monitoring with NOAA satellite data**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 86-89.
Advanced very high resolution radiometric data (AVHRR) was effective in monitoring spring growth patterns and senescence of annual grasses for fire management planning. The information was useful for ranking areas by fuel buildup and fire risk, and for identifying times when fire danger was high because on fuel quality.
prescribedfire, community-level, remote sensing, AVHRR, production, vegetation mapping.

847. Milne, A. 1959. **The centric systematic area-sample treated as a random sample**. Biometrics. 15: 270-297.
random sampling, design, plot selection, sampling design.

848. Minchin, P. R. 1987. **An evaluation of the relative robustness of techniques for ecological ordination**. Vegetatio. 69: 89-107.
analysis, multivariate analysis, ordination, similarity measures.

849. Minnich, R. A.; Barbour, M. G.; Burk, J. H.; Fernau, R. F. 1995. **Sixty years of change in Californian conifer forests of the San Bernardino Mountains**. Conservation Biology. 9: 902-914.
monitoring examples, permanent plots, forest, long-term ecological monitoring, community-level, community change.

850. Mitchell, J. E.; Brady, W. W.; Bonham, C. D. 1994. **Robustness of the point-line method for monitoring basal cover**. Res. Note RM-528. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p.
Computer simulations were used to test the effects of plant size, population distribution (random to contagious), and non-randomness of disturbance (simulated army tank tracks) on changes in cover measured by point intercept transects. Transects 100m long with 100 point intercepts were used to measure declines from an initial 12% cover to 10%, 8%, 6%, 4%, and 2% in a sampling universe approximately 113x8m. The method was robust with respect to plant size, plant distribution, and disturbance. The probability of detecting a decline from 12% to 10% with one transect was only about 7%, with 10 transects about 40%. The probability of detecting a larger change (decrease from 12% to 6%) was nearly 90% with 3 transects of 100 points.

community-level, field techniques, sampling design, design, sample size, community composition, cover, point intercept, power, canopy cover, detecting change, community change.

851. Moeur, M. 1992. **Baseline demographics of late successional western hemlock/western redcedar stands in northern Idaho research natural areas.** Res. Pap. INT-456. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 16 p.

Six permanent baseline plots were established in northern Idaho research natural areas to monitor natural development of old-growth western hemlock/western redcedar forests. Canopy density conditions were delineated and stratified for each study area, and 2 permanent plots were randomly located within each of 3 canopy strata (open, gappy, and closed). The rectangular plots ranged in size from 0.33 to 0.90 acres. Attribute data were collected for canopy trees and regeneration trees. Canopy trees were defined as trees at least 3in in diameter (DBH), including standing and down dead trees estimated to have been 3in DBH at time of death. Species, DBH, and crown ratio were recorded for every live canopy tree within a plot. All live canopy trees were permanently tagged with numbered aluminum tags and locations mapped with a transit. More detailed information was collected on a subsample to model tree height and crown width for every live canopy tree. To sample regeneration trees (less than 3in DBH and at least 0.5ft in height), the larger plot was divided into 25 non-overlapping subplots in which regeneration species composition, height class, and density class were recorded. On a smaller number of randomly selected subplots, individual regeneration trees were tallied. This detailed data allowed the author to produce excellent descriptive and graphic summaries of 1990 baseline demographic conditions for the 6 plots. For each plot, a series of 6 graphics portrays the following: 1) three-dimensional representation of the live overstory, showing mapped locations of trees; 2) mapped representation of regeneration trees; 3) histogram showing diameter distribution of live canopy trees by species; 4) histogram of canopy cover and trees per acre by height class; 5) histogram showing diameter distribution of dead canopy trees; and 6) regeneration height distribution. Plots are scheduled for a 10-year sampling interval.

monitoring examples, permanent plots, long-term ecological monitoring, natural areas, coniferous forest, tree, special sites, DBH, crown diameter, heights.

852. Moeur, M.; Stage, A. R. 1995. **Most similar neighbor: an improved sampling inference procedure for natural resource planning**. Forest Science. 41(2): 337-359.

sampling design, forest.

853. Moir, W. H.; Franklin, J. F. 1972. **Baseline measurement programs on federal research natural areas**. Rep. 1 (Review Draft). Corvallis, OR: Pacific Northwest Natural Areas Committee. 20 p.

This report, prepared for the Pacific Northwest Natural Area Committee, provides suggestions and examples of how to conduct ecological baseline measurement in natural areas. The authors identify 4 levels of baseline measurement, including activities such as reconnaissance inventories, checklists, engineering surveys, photo points, permanent plots, and more intensive ecosystem process studies. Throughout the report, references are made to useful papers and methodologies. Three types of permanent baseline plots and transects for measuring vegetation change in research natural areas are discussed in detail.

monitoring examples, field techniques, baseline monitoring, natural areas, natural areas, long-term ecological monitoring, species lists, permanent plots, photopoints, inventory, community-level, special sites, community change.

854. Monitoring and Assessment Research Centre. 1985. **Historical monitoring**. London: University of London. 320 p.

Historical monitoring involves the use of sediments, ice and snow, plant tissues, museum collections, herbarium specimens, and human remains to determine changes in chemical pollution levels over time. This report summarizes these techniques and sources of information.

monitoring examples, long-term ecological monitoring, environmental monitoring programs.

855. Montalvao, J.; Casado, M. A.; Levassor, C.; Pineda, F. D. 1991. **Adaptation of ecological systems: compositional patterns of species and morphological and functional traits.** Journal of Vegetation Science. 2: 655-666.

landscape-level, community-level, community composition, community structure, functional groups.

856. Montana, C. 1992. **The colonization of bare areas in two-phase mosaics of an arid ecosystem**. Journal of Ecology. 80: 314-327.

succession, species richness, general examples, community-level, community change, rangeland, functional groups.

857. Montgomery, R. H.; Reckhow, K. H. 1984. **Techniques for detecting trends in lake water quality**. Water Resources Bulletin. 20: 43-52.

analysis, trend analysis.

858. Moore, P. D.; Chapman, S. D. 1986. **Methods in plant ecology**. Oxford: Blackwell Scientific. 589 p.

analysis, field techniques, technique comparison.

859. Moore, W. H.; Swindel, B. F.; Terry, W. S. 1982. **Vegetative response to prescribed fire in a north Florida flatwoods forest**. Journal of Range Management. 35: 386-389.

field techniques, general examples, community change, prescribed fire, detecting change, succession, forest, canopy

cover, frequency, biomass, community composition, cover, community-level.

860. Morisita, M. 1957. **A new method for the estimation of density by the spacing method applicable to non-randomly distributed populations**. Physiology and Ecology. 7: 134-144.

This paper (in Japanese) is available in an English translation published by the Forest Service (Translation Number 11116). It describes the distance technique developed by Morisita that can be applied to aggregated populations.

field techniques, density, distance methods, angle-order.

861. Morris, M. J. 1973. **Estimating understory plant cover with rated microplots**. Res. Pap. RM-104. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

field techniques, ocular estimation, cover classes, cover.

862. Morrison, D. F. 1976. **Multivariate statistical methods. 2nd ed.** New York, NY: McGraw-Hill. 368 p.

The unique feature of this book is a chapter on matrix algebra, which provides the basis for understanding not only multivariate analyses, but also is good background reading for demography studies, many of which use analysis of transition matrices based on matrix algebra. Other subjects covered are standard for multivariate statistics texts: description of the multivariate normal distribution, repeated measures, two sample multivariate tests, MANOVA, linear discriminant functions, covariance matrices, principal components, and factor analysis.

analysis, multivariate analysis, classification, ordination, repeated measures analysis, statistics overview, demographic techniques.

863. Morrison, M. L. 1983. **Assessing changes and trends in wildlife habitat in a forest management context**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 101-103.

Frequency of occurrence of birds was compared by multiple regression to common forest stand inventory data attributes (basal area, annual growth, site index, density of stems, shrub cover, canopy height, and mean diameter). Only weak relationships were found, suggesting the inadequacy of standard timber inventory techniques to describe bird habitat quality. Increased cooperation is needed between foresters and wildlife biologists to design inventories and monitoring that could be used for both wildlife and timber purposes.

interdisciplinary design, monitoring and management, objectives, habitat mapping, inventory, forest.

864. Morrison, M. L. 1994. **Resource inventory and monitoring--concepts and applications for ecological restoration**. Restoration and Management Notes. 12(2): 179-183.

Monitoring approaches will vary depending on whether the focus is ecosystem elements of air, water, flora, fauna, etc., or the natural resources that are commodities and amenities for human use. Most restoration monitoring focuses on the basic ecosystem elements. Approaches will also vary depending on the spatial and temporal scale of the monitoring. Two types of inventory are recognized: category-driven, in which the inventoried elements are artificially constructed classes (such as old-growth or riparian areas), and attribute-driven, in which the inventoried elements are the actual natural elements. The latter is recommended, especially if inventory data will be repeatedly collected in a monitoring framework. Data collection must be carefully designed to avoid limited usefulness. A key characteristic is data that provide statistically unbiased estimates with known confidence intervals. In summary, an inventory or monitoring program requires: 1) identification of general goals; 2) development of specific objectives (target values of a resource with a defined mean and confidence interval, and, where appropriate, desired power); 3) articulation of the null hypothesis; 4) careful choice of study design and sampling techniques; 5) statistical analysis; and 6) application of results.

monitoring overviews, monitoring examples, ecological monitoring programs, monitoring definitions, monitoring and management, objectives, resource management, power, precision, confidence intervals, inventory, restoration.

865. Morrison, R. G.; Yarranton, G. A. 1970. **An instrument for rapid and precise sampling of vegetation**. Canadian Journal of Botany. 48: 293-297.

Accurate point intercepts are best done with a cross-hair sighting instrument to avoid error associated with the thickness of pins. An instrument was constructed from a rifle telescope sight, modified so it could be focused, and outfitted with a right angle prism at the end. The scope was mounted on a movable bracket on a 10ft long frame with telescoping legs. The right angle prism allows the viewer to look horizontally through the scope while the viewing field can be either directly below, directly above, or at a chosen angle.

field techniques, cover, canopy cover, point frames, point intercept, tools.

866. Moseley, J. C.; Bunting, S. C.; Hironaka, M. 1986. **Determining range condition from frequency data in mountain meadows of central Idaho**. Journal of Range Management. 39: 561-565.

Authors used nested frequency data to predict condition class in a grassland community. Species were classified as desirables, intermediates, and undesirables. Combined percent frequency of desirable and intermediate species predicted condition classes with 83% accuracy.

field techniques, frequency, meadow, herbaceous species, nested frequency, grassland, functional groups.

867. Moseley, J. C.; Bunting, S. C.; Hironaka, M. 1989. **Quadrat and sample size for frequency sampling mountain meadow vegetation**. Great Basin Naturalist. 49: 241-248.

field techniques, design, sampling design, frequency, plot dimensions, sample size, precision, meadow, grassland.

868. Moser, E. B.; Saxton, A. M. 1990. **Repeated measures analysis of variance: application to tree research**. Canadian Journal of Forest Research. 20: 524-535.

Repeated measures designs, in which measures are taken on the same individual (or experimental unit) several times over a given period, are common in tree physiology research (and also in monitoring). Because these measurements are not independent, it is incorrect to apply common univariate analyses. In this paper, an experiment investigating flooding and salinity effects on tree seedlings is used to illustrate some of the available analyses. Included are univariate and multivariate approaches to a single repeated measures factor (time), a repeated measures factor and between subjects factor (time x treatment), two repeated measures factors (day and hour), and two repeated measures factors combined with a treatment factor. Three studies from the literature are then reviewed and suggestions for improved analyses given.

seedling, analysis, permanent plots, repeated measures analysis, multivariate analysis, tree.

869. Motulsky, H. 1995. **Intuitive biostatistics**. London: Oxford University Press. 384 p.

This book is an introductory text that uses primarily non-mathematical explanations of standard statistics tests.

analysis, statistics overview.

870. Mouat, D. A.; Johnson, R. R. 1981. **Vegetation inventories and interpretation of environmental variables for resource management**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 300-307.

Vegetation is a useful management indicator because it is relatively stable, it can be mapped, often by remote sensing methods, and it synthesizes and integrates a number of physical factors. The use of vegetation patterns is illustrated by a case study in Grand Canyon National Park.

landscape-level, community-level, monitoring examples, pattern, ecosystem management, inventory, large-scale monitoring, integrated monitoring, remote sensing, national parks.

871. Mueggler, W. F. 1992. **Cliff Lake Bench Research Natural Area: problems encountered in monitoring vegetation change on mountain grasslands**. Res. Pap. INT-454. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 13 p.

Nested frequency and production measures were used to compare 1969 vegetation to 1988 condition on grassland and shrub grassland communities. Vegetation was measured with 48 plots (70x70cm) plots within each community. Production was estimated by comparison with similar nearby plots; frequency was based on all 48 plots. Production proved to be a poor indicator of change since an unknown portion of the change was due to yearly climatic differences. A portion of the differences was also assumed to be caused by a severe outbreak of grasshoppers in 1988. Frequency appeared a more reliable estimator of long-term change. In these grassland communities the $0.25m^2$ plot size was the most efficient and informative for nested frequency measures.

meadow, community-level, field techniques, frequency, community composition, community change, grassland, shrub grassland, nested frequency, production, natural areas, long-term ecological monitoring, technique comparison, design, plot dimensions, special sites.

872. Mueggler, W. F. 1976. **Number of plots required for measuring productivity on mountain grasslands in Montana**. Res. Note INT-207. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

The paper provides a formula for calculating sample size needed to achieve a desired precision if the standard error of the mean is known. A $4.8ft^2$ plot is recommended as the most efficient sampling unit size for measuring productivity in this vegetation type. The number of plots needed in order to obtain an 80% probability of being within 10% of the mean for key species within several habitat types ranged from 12 for *Bouteloua gracilis*, to 250 for *Agropyron spicatum* and 1250 for the sparsely distributed *Potentilla fruticosa*.

design, grassland, meadow, sampling design, plot dimensions, plot selection, sample size, precision, production.

873. Mueggler, W. F. 1994. **Sixty years of change in tree numbers and basal area in central Utah aspen stands**. Res. Pap. INT-478. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 11 p.

Permanent plots, ranging in size from 0.18 to 0.5 acres, were established in 3 stands. In each stand, sampling was done in 2 contiguous plots, one of which was thinned and the other left untreated. All trees were tagged and measured for diameter (DBH) at the start of the study in 1913. Plots were inventoried sporadically until 1977. Although changes at the 3 sites differed, general conclusions about stand dynamics could be made.

monitoring examples, deciduous forest, density, DBH, permanent plots, vegetation treatments, long-term ecological monitoring, tree, demographic techniques.

874. Mueller-Dombois, D.; Ellenberg, H. 1974. **Aims and methods of vegetation ecology**. New York, NY: John Wiley and Sons. 547 p.

field techniques, vegetation sampling overview.

875. Muir, P. S.; McCune, B. 1992. **A dial quadrat for mapping herbaceous plants**. Natural Areas Journal. 12: 136-138.
tools, charting, demographic techniques, rare species.

876. Munn, R. E. 1988. **The design of integrated monitoring systems to provide early indications of environmental/ecological changes**. Environmental Monitoring and Assessment. 11: 203-217.
monitoring examples, ecological monitoring programs, monitoring overviews, detecting change.

877. Murkin, E. J.; Murkin, H. R. 1989. **Marsh ecology research program: long-term monitoring procedures manual**. Tech. Bull. 2. Delta, Manitoba, Canada: Delta Waterfowl and Wetlands Research Station. 63 p.

The Delta Marsh in south-central Manitoba is the site of a long-term experimental study in which 10 contiguous 4 to 6ha diked units are given one of 4 different drawdown and flooding treatments. This publication summarizes the techniques used to measure the response of the marsh over several years. Covered are the measures of annual climatic factors, physical factors (sediment, water temperature, soils), hydrology, nutrient dynamics, algal and macrophyte production, cover changes (assessed from aerial photographs), decomposition, invertebrates, and vertebrates. Of these, only the discussion of cover mapping is directly applicable to terrestrial vegetation monitoring. Cover is determined from photographs made from a height of 610m. Mapping is done during the field season the photographs are taken to allow ground truthing. During ground truthing, water depths are measured at 5 locations within each dominant cover type. Interpretation of cover changes is facilitated by an overlay contour map of water depths using a 10cm interval. All maps are digitized to allow GIS analysis and manipulation.

long-term ecological monitoring, monitoring examples, field techniques, wetland, meadow.

878. Murphy, D. D. 1990. **Conservation biology and scientific method**. Conservation Biology. 4: 203-204.

The author defines conservation biology as the "application of classical scientific methodology to the conservation of biological diversity." Research in the field of conservation biology must have practical applications to management, policy, and decision-making. The author contends that reserve management plans should follow the scientific method, with management strategies and options recognized as hypotheses. Implementation and monitoring the effects of these strategies is the experiment.

design, special sites, monitoring and management, objectives.

879. Murray, R. B.; Jacobson, M. Q. 1982. **An evaluation of dimension analysis for predicting shrub biomass**. Journal of Range Management. 35(4): 451-454.

Measuring biomass by actual clipping and weighing is an extremely time-consuming process, so finding a consistent relationship between a more easily measured parameter and biomass is desirable. In this study crown diameters, height, and number of multiple stems were measured on 50 to 100 individuals of 4 different species. Each individual was then harvested at the ground, and separated into the leaf fraction and 7 categories of live and dead stems (based on stem diameters). The measures were used to generate dimensions of circumference, surface area, and volume for 8 typical volume shapes (sphere, elliptical cylinder, etc.). These were compared to actual biomass using several mathematical relationships (e.g., simple linear, logarithmic). The best predictors were simple linear models using surface area or volume.

community composition, shrubland, biomass, crown diameter, production, heights, field techniques, shrub.

880. Musselman, R. C., tech. coord. 1994. **The Glacier Lakes Ecosystem Experiments Site**. Gen. Tech. Rep. RM-249. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 93 p.

The Glacier Lakes Ecosystem Experiment Site (GLEES), located in the Snowy Range of southern Wyoming, was established to study the effects of atmospheric deposition in alpine and subalpine environments. This publication reports preliminary data from studies integrating vegetation, geology, soils, aquatics, hydrology, air quality, and meteorology. Initial vegetation work includes vegetation and habitat mapping and floristic studies. The authors mention that a large number of permanent vegetation plots have been established on the site but give no description of them.

ecological monitoring programs, global change monitoring, monitoring examples, long-term ecological monitoring, integrated monitoring, permanent plots, field techniques.

881. Myers, C. A. 1961. **Variation in measuring diameter at breast height of mature ponderosa pine**. Res. Notes RM-67. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p.
field techniques, DBH, observer variability, tree.

882. Myers, R. M. 1960. **Range utilization exclosure**. Journal of Range Management. 13: 40.

A utilization cage for excluding livestock from small plots is described. The cage is pyramidical, 5ft square at the base. The frame is made of 3/8in steel reinforcing rod and is covered with 2x4in woven wire, welded to the frame. The shape of the frame allows for easy stacking and transport.

field techniques, utilization, tools.

883. Myster, R. W.; Pickett, S. T. A. 1994. **A comparison of rate of succession over 18 years in 10 contrasting old fields**. Ecology. 75: 387-392.
succession, community-level, community change, meadow.

884. Nash, A. J. 1981. **Logistical inventory problems in tropical areas**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 68-72.
Although focused on inventory in tropical areas, the discussion in this paper is also applicable to monitoring situations in any remote area. Efficient use of field crews depends on the detailed knowledge of the planner, the design of the sampling (tradeoff between increased efficiency of cluster sampling and decreased variance with one-stage sampling) and the choice of vehicle travel. An example illustrating the planning of a large tropical forest inventory is presented.
design, objectives, inventory, forest, large-scale monitoring, integrated monitoring, sampling design.

885. National Science Foundation. 1977. **Long-term measurements: report of a conference**. Washington, DC: National Science Foundation Directorate for Biological, Behavioral, and Social Sciences.
monitoring examples, long-term ecological monitoring.

886. National Swedish Environment Protection Board. 1985. **Monitor 1985 - the national Swedish environmental monitoring programme**. Stockholm, Sweden: National Swedish Environmental Protection Board.
monitoring examples, environmental monitoring programs.

887. Neal, D. L.; Hubbard, R. L.; Conrad, C. E. 1969. **A magnetic point frame**. Journal of Range Management. 22: 202-203.
field techniques, tools, point frames, cover, point intercept.

888. Neal, D. L.; Ratliff, R. D.; Westfall, S. E. 1988. **A quadrat frame for backcountry vegetation sampling**. Journal of Range Management. 41: 353-355.
This article provides directions for constructing a light-weight portable quadrat frame. The 30x30cm frames (210g) were made from round bar and drawn square tubing of 6061-T6 aluminum alloy. They are easily assembled with an allen wrench. The authors suggest anodizing the frames for corrosion protection, a cleaner surface to handle, and a bright color for visibility. A frame storage case for backpacking was made from 1¼in PVC pipe with end caps.
field techniques, permanent plots, tools.

889. Neave, H. R.; Worthington, P. L. 1988. **Distribution-free tests**. London: Unwin Hyman. 430 p.
analysis, statistics overview, nonparametric statistics.

890. Nelson, E. W. 1930. **Methods of studying shrubby plants in relation to grazing**. Ecology. 11: 764-769.
field techniques, shrub, shrubland, cover, density.

891. Nelson, R. F. 1983. **Detecting forest canopy change due to insect activity using Landsat MSS**. Photogrammetric Engineering and Remote Sensing. 49(4): 1303-1314.
remote sensing, canopy cover, forest, Landsat, MSS.

892. Nelson, R.; Gregoire, T. G. 1994. **Two-staged sampling: a comparison of three procedures to estimate aggregate volume**. Forest Science. 40: 247-266.
design, sampling design, two-stage sampling, tree.

893. Nerney, N. J. 1960. **A modification for the point-frame method of sampling range vegetation**. Journal of Range Management. 13: 261-262.
The author describes mounting a point frame on a bicycle wheel to increase the efficiency of point sampling. The frame is a 10 pin assembly, with pins at 2in intervals. The bicycle wheel has a metal strap that contacts the fork of the wheel frame with each revolution, and marks the location of the next frame. Each revolution of the wheel is approximately 7ft. Using the counter mechanism helps avoid bias in placement of the pin frame. The wheel/frame assembly forms a stable tripod when set down, allowing the investigator free hands while measuring. The device worked well along transects in short-grass range vegetation.
field techniques, cover, rangeland, grassland, canopy cover, point frames, point intercept, systematic sampling, tools.

894. Newman, A. P. 1993. **Monitoring urban forest canopy cover using satellite imagery**. Environmental Monitoring and Assessment. 26: 175-176.
forest, tree, remote sensing, Landsat, canopy cover.

895. Newton, P. F. 1994. **Comparison of sequential and double sampling designs for estimating point density within seedling populations**. Canadian Journal of Forest Research. 24: 1472-1479.
design, density, seedling, sampling design, sample size, precision.

896. Nicholas, N. W.; Gregoire, T. G.; Zedakers, S. M. 1991. **The reliability of tree crown position classification**. Canadian Journal of Forest Research. 21: 698-701.
tree, observer variability, field techniques.

897. Nichols, J. D. 1981. **Intra-cluster correlation in sample design**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 20-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 142-147.

Cluster sampling is designed to reduce sampling costs associated with travel time between plots. But because clusters of plots tend to be similar to each other (intracluster correlation), more plots are needed to sample with the same precision achieved with fewer plots distributed randomly over the landscape. There is thus a design trade-off between travel time and number of plots. A model is presented that shows the increase number of plots required by various autocorrelation levels.

design, cluster sampling, sampling design, random sampling, precision.

898. Nieppola, J. 1992. **Long-term vegetation changes in stands of *Pinus sylvestris* in southern Finland**. Journal of Vegetation Science. 3: 475-484.

Permanent plots (50x50m) were established in 112 pine forest stands in 1950 to 1956, and were resampled in 1983 to 1986. About half of these stands were clearcut and the rest thinned at various levels at some point during the period between the 2 measurements. All trees were measured for diameter (DBH) and a sample of largest trees for height. Understory species were estimated to cover classes in twenty 1x1m plots placed systematically along the diagonals. A paired t-test was used to test the differences in mean cover for each species between the 2 measurements.

monitoring examples, community-level, tree, cover, community change, community composition, community structure, succession, coniferous forest, ocular estimation, cover classes, frequency, DBH, permanent plots, heights.

899. Nilsson, C. 1992. **Increasing the reliability of vegetation analyses by using a team of two investigators**. Journal of Vegetation Science. 3: 565.

The author describes ongoing work that censuses and estimates cover of vascular plants in a 200m length of riparian area using 2 workers, each working independently from opposite sides of the transect. In over 350 sampling units, there was never a complete agreement between the 2 observers. Observers must rectify discrepancies and come to consensus on differences in cover estimates before leaving the unit.

field techniques, community-level, cover, cover classes, observer variability, species lists, ocular estimation.

900. Nilsson, C.; Eckblad, A.; Gardfjell, M.; Carlberg, B. 1991. **Long-term effects of river regulations on river margin vegetation**. Journal of Applied Ecology. 28: 963-987.

The effects of hydrologic development on riparian vegetation was evaluated by comparing two similar rivers. Vegetation along the 400km rivers was measured by dividing each stream into 25 sections of equal length and sampling the center of each of these with a 200m long transect (see Nilsson 1992). All species along this transect were recorded and percent cover for each estimated. Environmental factors of width and height of river margin, substrate fineness, mean annual discharge, and water level regime was measured at each sampling area. To test differences by functional class, species were grouped in four ways: morphology, naturalness (natural versus introduced or ruderal species), location (shoreline and terrestrial versus aquatic), and life span (perennial versus annuals and biennials). Differences in these functional classes, environmental measures, and vegetation measures (e.g., overall species richness, species richness in each of the species groups, percent cover of woody species) were compared with a Mann-Whitney-U test. This analysis identified a number of significant differences between the two rivers.

biodiversity, disturbance, landscape change, community composition, community structure, cover, predicting change, species lists, canopy cover, nonparametric statistics, detecting change, large-scale monitoring, community structure, general examples, community-level, field techniques, cover, landscape-level, riparian.

901. Nilsson, C.; Keddy, P. A. 1988. **Predictability of change in shoreline vegetation along a hydroelectric reservoir, northern Sweden**. Canadian Journal of Botany. 45: 1896-1904.

natural variability, predicting change, objectives, riparian.

902. Nilsson, I. N.; Nilsson, S. G. 1985. **Experimental estimates of census efficiency and pseudoturnover on islands: error trend and between-observer variation when recording vascular plants**. Journal of Ecology. 73: 65-70.

Vascular plant presence was censused on 41 islands ranging in size from 0.03 to 2.19ha in 4 searches between 1976 and 1982. In the final year, the earlier species lists were examined after the first census period of 200 minutes per hectare (min/ha), and with additional search time (up to 100min/ha) an attempt made to locate missing species. To compare observer differences, a second team of botanists inventoried each island for approximately 300min/ha. The standard searches found only 74% to 87% of the total number of species recorded with the additional search time. Up to 20% of the total number of species located by both teams were located by only one of the teams and not the other. A second method of supplementing the standard search list was to grid the island into squares (1x1m) and search each square at least twice. Even with this intensity, only about 80% of the species located by all searchers and all methods were recorded.

community-level, community change, community composition, species richness, species lists, species diversity, observer variability.

903. Nilsson, S. G.; Nilsson, I. N. 1983. **Are estimated species turnover rates on islands largely sampling errors?** American Naturalist. 121: 595-597.

As part of a study on species turnover on 41 small islands (change in species due to immigration and extinction), 6 islands ranging in size from 0.03 to 1.04ha were surveyed twice by the same investigators. The surveys were one week apart, and the difference in species composition was termed

"pseudoturnover" by the investigators. Pseudoturnover on these 6 islands averaged 8% (6.3% to 11.6%). This rate of error has implications for the use of species lists or species richness as a monitoring tool.

community-level, observer variability, community composition, species richness, species lists, species diversity.

904. Noble, I.; Norton, G. 1991. **Economic aspects of monitoring for national park management.** In Margules C. R.; Austin M. P., eds. Nature conservation: cost effective biological surveys and data analysis. Canberra, Australia: CSIRO (Commonwealth Scientific and Industrial Research Organization): 69-73.

monitoring and management, special sites, wilderness, national parks, objectives.

905. Noble, I. R.; Slayter, R. O. 1980. **The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances**. Vegetatio. 43: 5-21.

community-level, objectives, predicting change, community change, succession, disturbance.

906. Norton, B. E. 1978. **The impact of sheep grazing on long-term successional trends in salt desert shrub vegetation in southwestern Utah**. In: Hyder, D. N., ed. Proceeding of the 1st International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 610-613.

In 1935, 32 exclosures (each about 1 acre) were established in salt desert shrub vegetation in an area grazed by sheep. In each exclosure 2 permanent 5x20ft plots were established and paired with 2 plots placed outside the exclosure. All perennial plants in each plot were drawn to scale on grid paper, with dead plants and parts of plants shaded in. Plots were mapped 4 times between 1935 and 1975. Plant cover was calculated based on the number of squares occupied by a species on the gridded map. Total plant cover changed from 4% to 8% on grazed sites, and from 5% to to 11% on the ungrazed plots over the 40 years. Changes in cover by species were similar between the 2 grazing treatments, but the ungrazed site had generally higher cover values. The parallel patterns of change suggests that climate or some other factor exerted a stronger influence on community dynamics than grazing treatment.

community-level, field techniques, succession, community change, monitoring examples, long-term ecological monitoring, shrub grassland, cover, charting.

907. Noss, R. 1990. **Indicators for monitoring biodiversity: a hierarchical approach**. Conservation Biology. 4(4): 355-364.

landscape-level, biodiversity, monitoring overviews, indicators.

908. Noss, R. F.; Cooperrider, A. Y. 1994. **Saving nature's legacy -- protecting and restoring biodiversity**. Washington, DC: Island Press. 416 p.

This book provides a framework for a broad, land-based strategy for conserving biodiversity in the United States, synthesizes information, and offers guidelines to those involved in biodiversity conservation. One chapter of this book focuses on the topic of monitoring. The authors introduce the concept of adaptive management and describe different types of monitoring and associated problems. The basic premise is that in order to conserve biodiversity, we need a better understanding of ecological systems and components and how they respond to various management practices. This chapter emphasizes "effectiveness monitoring" which addresses the question of whether the management had the intended effect. The authors identify a series of steps in developing a monitoring program: scoping and definition of monitoring goals, inventory, design and indicator selection, sampling, model validation, and data analysis and management. A useful table shows the relationship between management and monitoring goals. Another table identifies possible indicators (and tools) for monitoring composition, structure, and function at different ecological levels from genetic to regional landscapes. The authors illustrate these monitoring program steps with a hypothetical situation in the Blue Mountains of Eastern Oregon. The chapter concludes with a set of guidelines helpful to anyone developing a monitoring program.

monitoring and management, landscape-level, monitoring examples, ecological monitoring programs, biodiversity, indicators, objectives, monitoring definitions.

909. Nowacki, G. J.; Abrams, M. C. 1994. **Forest composition, structure, and disturbance history of the Alan Seeger Natural Area, Huntington County, Pennsylvania.** Bulletin of the Torrey Botanical Club. 121(3): 277-291.

This paper provides an example of an in-depth analysis of vegetation composition, structure, and disturbance history in an old-growth eastern hemlock forest in Pennsylvania (Alan Seeger Natural Area). Ten forest stands were sampled in detail utilizing the point-quarter method to estimate forest structure and composition. Vegetation measurements included tree diameter (DBH) and canopy position, sapling and seedling density, and shrub and herbaceous canopy cover. In order to reconstruct past stand histories, several trees were selected for age and tree-ring chronology analysis. Topographic and soils data were also collected. The resulting data allowed the authors to interpret vegetation responses and patterns to stand disturbance history. This study also emphasized the important ecological values of natural areas for providing insights into changes in vegetation and other ecological relationships over time.

special sites, community-level, landscape-level, natural areas, tree-ring analysis, disturbance, forest, succession, point-center methods, community structure, community composition, DBH, monitoring examples, canopy cover, field

techniques, cover, density, distance methods, tree, reference areas, seedling.

910. Nowling, S.; Tueller, P. T. 1993. **A low-cost multispectral airborne video image system for vegetation monitoring on range and forest lands**. Proceedings of the 14th biennial workshop on color aerial photography and videography for resource monitoring; 1993 May 25-29; Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 1-8.

The article describes the ongoing development of an airborne video system. Three to four cameras acquire data from specific spectral bands, which can be chosen to match the ones used by the Landsat Thematic Mapper. The data are immediately captured in frames of 512x512 pixels onto a computer disk at the rate of 30 frames per second. A global positioning system is used to indicate the location of the center of the frame. Depending on the resolution of components of the system, accuracy of location ranges from 1 to 5m. These data can be analyzed using geographic information systems. The key value to the video system is low cost and immediate data capture and opportunity for analysis. The authors suggest, among other applications, repeat vegetation mapping of riparian corridors, evaluation of changes due to grazing, monitoring of vegetation changes and success of treatments, monitoring of weed infestations, and monitoring of forest health indicators such as insect damage and blowdown.

pattern, landscape change, vegetation treatments, community composition, community structure, vegetation mapping, GPS, GIS, Landsat, remote sensing, landscape-level, community-level, TM, aerial photography, video.

911. Nyssonen, A. 1967. **Remeasured sample plots in forest inventory**. Vollebekk, Norway: Norwegian Forest Research Institute. 25 p.

field techniques, permanent plots, tree, forest, inventory.

912. O'Brian, R. G.; Kaiser, M. K. 1985. **MANOVA method for analyzing repeated measures designs: an extensive primer**. Psychology Bulletin. 97: 316-333.

analysis, repeated measures analysis, MANOVA.

913. O'Brien, R. 1989. **Comparison of overstory canopy cover estimates on forest survey plots**. Res. Pap. INT-417. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 5 p.

observer variability, cover, canopy cover, ocular estimation, tree, field techniques.

914. O'Brien, R.; Van Hooser, D. D. 1983. **Understory vegetation inventory: an efficient procedure**. Res. Pap. INT-323. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.

monitoring examples, ecological monitoring programs, large-scale monitoring, inventory.

915. O'Conner, T. G.; Roux, P. W. 1995. **Vegetation changes (1949-1971) in a semi-arid, grassy dwarf shrubland in the Karoo, South Africa: influence of rainfall variability and grazing by sheep**. Journal of Applied Ecology. 32: 612-626.

long-term ecological monitoring, grassland, shrubland, natural variability, community-level, community change, general examples.

916. Oderwald, R. G. 1981. **Point sampling and plot sampling--the relationship**. Journal of Forestry. 79: 377-378.

sampling design, design, variable plots, field techniques, density, basal area, technique comparison.

917. Odum, E. P. 1985. **Trends expected in stressed ecosystems**. BioScience. 35: 419-422.

landscape-level, ecosystem, disturbance, predicting change, monitoring and management.

918. Ohmann, L. F. 1973. **Vegetation data collection in temperate forest research natural areas**. Res. Pap. NC-92. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 35 p.

monitoring examples, forest, tree, special sites, field techniques, natural areas, vegetation sampling overview, ecological monitoring programs.

919. Ojima, D. S.; Kittel, T. G. F.; Rosswall, T.; Walker, B. H. 1991. **Critical issues for understanding global change effects on terrestrial ecosystems**. Ecological Applications. 1(3): 316-325.

general examples, objectives, global change monitoring, detecting change.

920. Oldemeyer, J. D.; Regelin, W. L. 1980. **Comparison of nine methods for estimating density of shrubs and saplings in Alaska**. Journal of Wildlife Management. 44(3): 662-666.

field techniques, density, technique comparison, plotless methods, shrub.

921. Oliver, I.; Beattie, A. J. 1993. **A possible method for the rapid assessment of biodiversity**. Conservation Biology. 3: 562-568.

Flowering plants and vertebrates are often used as surrogates for measures of biodiversity, but the correlation between the diversity of these organisms and other classes such as invertebrates is not consistent. Developing species lists of invertebrates, however, requires specialized skills and is expensive. In this study, a technician was given training in the taxonomy of spiders, polychaetes, mosses, and ants (12 hours total). The technician then separated the collections into "Recognizable Taxonomic Units"(RTUs). The collections

were also identified by a specialist. The ratio of species to RTUs was 83-88% for spiders and ants, with only a small amount of lumping of two or more species into a single RTU or splitting of species into two or more RTUs. The correspondence was lower and degree of lumping and splitting much higher for polychaetes and mosses. The authors suggest that using RTUs and technicians may be a cost-effective way to assess biodiversity of abundant and lesser known organisms.

landscape-level, ecosystem management, biodiversity, species lists, diversity indices, inventory.

922. Olson, C. M. 1992. **Monitoring species diversity: a sampling approach**. In: Kerner, H. M., ed. Symposium on biodiversity of northwestern California. Berkeley, CA: University of California, Wildland Resources Center, Division of Agriculture and Natural Resources: 30-35.

landscape-level, community-level, community change, diversity indices, biodiversity, species diversity, species richness.

923. Omule, S. A. Y. 1980. **Personal bias in forest measurements**. Forestry Chronicle. 56(5): 222-224.

observer variability, field techniques, DBH, tree, forest.

924. O'Neill, R. V.; Hunsaker, C. T.; Levine, D. A. 1992. **Monitoring challenges and innovative ideas**. In: McKenzie, D. H.; Hyatt, D. E.; McDonald, V. I., eds. Ecological indicators. Amsterdam: Elsevier Applied Scientific Publishers: 1443-1460.

Large monitoring programs such as EPA's Environmental Monitoring and Assessment Program (EMAP) often have multiple objectives in order to gain support from many sources. The objectives of EMAP are four: 1) estimate the extent of resources and their geographical distribution; 2) determine the percent in acceptable/improving and unacceptable/degrading condition; 3) correlate these ecosystem conditions with human impacts and identify causes of decline; and 4) anticipate and identify undesirable changes before they become crises. The authors argue that such objectives raise unrealistic expectations because it is unlikely that monitoring a set of indicators will be able to determine ecosystem health, relate trends to causal mechanisms, or predict which trends will develop into crises. A key problem is that the concept of ecosystem health is a human one that depends on the bias, values, and objectives of the definer. The authors suggest that innovative approaches to monitoring are needed that utilize integrative measures of critical ecosystem functions. Some potential measures are the ratio of primary production to respiration, energy flow per unit biomass, decomposition rates, gas exchange, and nutrient cycling. Another approach is to use landscape level indicators monitored by remote sensing. Changes in classification of pixels can be used to measure changes in forest cover (which translates into habitat loss), the number of road miles (fragmentation), and the ratio of human-related classes to natural. Changes in pattern can also be monitored. These values can be related to functions and processes. For example, land cover changes could be weighted by distance from water, soil type, and slope to determine the potential for erosion, thus identifying trouble spots and overall trends.

ecological monitoring programs, monitoring examples, adaptive management, monitoring and management, objectives, disturbance, ecological processes, ecosystem, ecosystem management, indicators, fragmentation, landscape planning, pattern, landscape change, regional planning, long-term ecological monitoring, remote sensing, landscape-level, indicators.

925. O'Neill, R. V.; Turner, J.; Cullinan, V. I.; Coffin, D. P.; Cook, T.; Conley, W.; Brunt, J.; Thomas, J. M.; Conley, M. R.; Gosz, J. 1991. **Multiple landscape scales: an intersite comparison**. Landscape Ecology. 5: 137-144.

analysis, landscape-level, community comparisons, landscape change, scale.

926. Oosterhuis, L.; Oldeman, R. A. A.; Sharik, T. L. 1982. **Architectural approach to analysis of North American temperate deciduous forests**. Canadian Journal of Forest Research. 12: 835-847.

community-level, community structure, forest, deciduous forest, tree.

927. Ord, J. K.; Patil, G. P.; Taillie, C., eds. 1979. **Statistical distributions in ecological work**. Patil, G. P., series ed. Statistical ecology series, volume 4. Fairland, MD: International Cooperative Publishing House. 410 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "Chance Mechanisms Underlying Univariate Distributions," "Chance Mechanisms Underlying Multivariate Distributions," "Ecological Contributions Involving Statistical Distributions," "Some Recent Developments Relating to Statistical Distributions in Forestry and Forest Products Research," "On the Use of Abundance and Species-Abundance Curves," "A Basic Development of Abundance Models: Community Descriptions," and "Species Area Curves."

analysis, statistics overview, pattern, time series, species richness, species diversity.

928. Orloci, L. 1975. **Multivariate analysis in vegetation research**. The Hague, the Netherlands: Junk. 276 p.

analysis, multivariate analysis.

929. Orloci, L.; Rao, C. R.; Stiteler, W. M., eds. 1979. **Multivariate methods in ecological work**. Patil, G. P., series ed. Statistical ecology series, volume 7. Fairland, MD: International Cooperative Publishing House. 395 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring

situations: "Analysis of ecological frequency data: certain case studies," "Non-linear data structure and their description," "Confidence intervals for similarity measures using the two sample jackknife," and "A comparison of twenty measures of site dissimilarity."

analysis, multivariate analysis, confidence intervals, similarity measures, randomization tests, frequency.

930. Orodho, A. B.; Trlica, M. J.; Bonham, C. D. 1990. **Long-term heavy grazing effects on soil and vegetation in the Four Corners region**. The Southwestern Naturalist. 35: 9-14.

Paired 50x75m plots inside and outside a 50-year-old exclosure were used to compare soil characteristics and vegetation on three topographic positions. Visual estimates of cover, litter, and bare ground were made in forty-five 20x50cm quadrats within each plot. Biomass harvest was completed on 20% of these. Density was measured with 30 point-center quarter samples in each plot. The paired plots were analyzed as a randomized complete block design with a factorial arrangement of treatments. Analysis of variance was used for all data from the 3 topographic sites for grazed and ungrazed plots. The only significant differences were higher litter cover and shrub density in the ungrazed plots.

ocular estimation, field techniques, density, distance methods, cover, shrub, herbaceous species, community-level, point-center methods, detecting change, canopy cover, density, shrub grassland, community change, rangeland.

931. Ortiz, M.; Amers, M. 1992. **Viewpoint: sample adequacy for point analysis depends on the objectives**. Journal of Range Management. 45: 595.

This paper is a response to Hofmann and Ries (1990) which examined sample size needed to determine adequacy of vegetation cover on revegetated mine sites which must be at least 90% of the reference site cover with a 90% confidence. The authors point out that one of the Hofmann and Ries equations uses 0.10, rather than 0.10(p), or 10% of the reference cover. This error increases the sample size by a factor of 15. The key problem with the Hofmann and Ries paper, however, is that the approach given is not the solution to the real issue. The formulas given by Hofmann and Ries are for calculating sample size to be 90% confident that the cover can be estimated to within 10% of the reference mean, whatever the actual cover. The real question is to ask how large a sample is required to determine with a 10% error rate that the mean cover of the revegetated site is at least 90% of the reference mean cover. This cannot be easilyanswered, however, because it depends on how close the tested mean is to that 90% value (if the revegetation site cover is very close to the 90% value, a larger sample size will be needed to measure it with the desired confidence).

design, field techniques, cover, precision, sample size.

932. Osburn, W. S. 1980. **National environmental research parks: a framework for environmental health monitoring**. In Worf, D. L., ed. Biological monitoring for environmental effects. Lexington, MA: Lexington Books, D. C. Health and Company: 143-150.

The intent of the National Environmental Policy Act (NEPA) is that humans should use the environment to achieve a high quality of life (both economically and aesthetically) and preserve for future generations the same environmental opportunities that exist currently. To meet this intent, a coordinated national system of monitoring environmental health is needed. National Environmental Research Parks centered around large Department of Energy lab sites are proposed to serve as research sites to assess the ecological impact of man's activities and technology. The initial objectives for each site are to 1) compile an ecological profile of the region, including species lists, characterization of species response to environmental stresses, soil maps, hydrology, etc.; 2) set aside research reference areas or natural areas; 3) establish protected areas of high natural genetic diversity; 4) establish data centers for storage and retrieval of regional ecological information; 5) develop and improve analysis techniques; 6) perform ecological experiments; 7) identify indicators; 8) provide sites for successional studies; and 9) educate the public.

monitoring examples, special sites, natural areas, monitoring and management, indicators, regional planning, species lists, long-term ecological monitoring, integrated monitoring.

933. Oswald, B. P.; Covington, W. W. 1983. **Changes in understory production following a wildfire in southwestern ponderosa pine**. Journal of Range Management. 36: 507-509.

The authors report on a study to measure and monitor changes in vegetation following a wildfire in a ponderosa pine stand on the Coconino National Forest in northern Arizona. Plots were established in moderately and severely burned and control areas immediately following the fire in 1972. Plots were remeasured in 1974 and 1980. A total of 30 timber inventory plots (0.04 hectares) were permanently located along transects perpendicular to the long axis of the sample area. At each of these reference points an additional set of 4 vegetation microplots ($0.89m^2$) were established. Within each microplot, stem counts were made for each species and vegetation was clipped to determine production and species composition.

monitoring examples, herbaceous species, tree, forest, production, disturbance, succession, permanent plots, community-level, community change, prescribed fire.

934. Ott, L. 1977. **An introduction to statistical methods and data analysis**. Belmont, California: Duxbury Press. 730 p.

analysis, statistics overview.

935. Ott, W. R. 1978. **Environmental indices**. Ann Arbor, Michigan: Ann Arbor Science.

landscape-level, indicators.

936. Ott, W. R. 1995. **Environmental statistics and data analysis**. Boca Raton, FL: Lewis Publishers. 336 p.
analysis, statistics overview.

937. Owen, W. R.; Rosentreter, R. 1992. **Monitoring rare perennial plants: techniques for demographic studies**. Natural Areas Journal. 12: 32-38.
rare species, demographic techniques, field techniques, monitoring examples.

938. Owens, M. K.; Gardiner, H. G.; Norton, B. E. 1985. **A photographic technique for repeated mapping of rangeland plant populations in permanent plots**. Journal of Range Management. 38: 231-232.

The authors constructed a portable camera stand from light-weight aluminum which can be positioned over permanent rebar stakes marking photoplots. A schematic and dimensions of the stand are provided in the article. The stand has a maximum height of 7m and photoplot size of 3.5x4m. Both 35mm and 70mm cameras with different lens were tested; best results were achieved with the 70mm camera. This method was developed for mapping and monitoring range plots, but could have much broader application. Mapping from photos was accomplished by hand, but computer techniques could now be applied for this analysis.
field techniques, tools, photoplots, vegetation mapping, permanent plots, rangeland.

939. Owensby, C. E. 1973. **Modified step-point system for botanical composition and basal cover estimates**. Journal of Range Management. 26: 302-303.
field techniques, cover, point intercept, basal area.

940. Pacala, S. W.; Canham, C. D.; Saponara, J.; Silander, J. A.; Kobe, R. K.; Ribbens, E. 1996. **Forest models defined by field measurements: estimation, error analysis and dynamics**. Ecological Monographs. 66(1): 1-43.
ecological models, forest, precision, sampling design.

941. Pakarinen, P. 1984. **Cover estimation and sampling of boreal vegetation in northern Europe**. In: Knapp, R., ed. Sampling methods and taxon analysis in vegetation science. Handbook of vegetation science, volume 4. The Hague: Junk: 35-44.
field techniques, cover, arctic, herbaceous species, ocular estimation, multivariate analysis.

942. Palmer, C. J.; Ritters, K. H.; Strickland, J.; Cassell, D. C.; Byers, G. E.; Papp, M. L.; Liff, C. I. 1991. **Monitoring and research strategy for forests - Environmental Monitoring and Assessment Program (EMAP)**. EPA/600/4-91/012. Washington, DC: U.S. Environmental Protection Agency.
monitoring examples, ecological monitoring programs, long-term ecological monitoring, large-scale monitoring, forest.

943. Palmer, M. E. 1987. **A critical look at rare plant monitoring in the United States**. Biological Conservation. 39: 113-127.

Based on surveys sent to state heritage programs and federal agencies, the types and extent of rare plant monitoring is summarized.
rare species, demographic techniques, objectives, monitoring examples.

944. Palmer, M. W. 1990. **The estimation of species richness by extrapolation**. Ecology. 71: 1195-1198.

Estimating species richness of plants usually involves using quadrats in which species abundance or presence is recorded. Community richness from this sample is estimated based on 1 of 4 estimator types: 1) number of observed species in the plots; 2) use of species-area curves to extrapolate to the entire area; 3) integration of the log-normal relationship of number of species and abundance; and 4) nonparametric approaches such as the jackknife and the bootstrap. The author developed a complete species list for thirty 0.1ha macroplots, and sampled each of these with forty $2m^2$ quadrats during the spring. The nonparametric models (the first and second order jackknife and the bootstrap) performed better than the other approaches. The first order jackknife was the most precise and least biased. All estimators, however, except for two species-area curve models, underestimated species richness. Another of the species-area curve models underestimated species richness, but provided the best correlation, and may be a good choice for spatial or temporal comparisons.
analysis, community-level, biodiversity, community composition, species richness, species lists, species diversity, deciduous forest, cover classes, nonparametric statistics, randomization tests, jackknife, bootstrap.

945. Palmer, M. W. 1991. **Estimating species richness: the second order jackknife reconsidered**. Ecology. 72: 1512-1513.

This paper is a correction of Palmer (1990) in which an incorrect formula for the second order jackknife was used. Based on modelling with the corrected formula, the second-order jackknife is superior if an unbiased estimator is required, but the first-order jackknife provides a more precise estimate.
community-level, analysis, biodiversity, community composition, species richness, species lists, species diversity, deciduous forest, cover classes, nonparametric statistics, randomization tests, jackknife.

946. Palmer, M. W. 1993. **Potential biases in site and species selection for ecological monitoring**. Environmental Monitoring and Assessment. 26: 277-282.

The author argues that the "law of regression" results in a tendency for things to become less extreme over time. The author draws 3 conclusions. First, rare species will, on average, appear to increase in abundance over time. Species that are rare at a certain point in time may actually be more

common on average, but are simply being observed at a low point in their fluctuating population size. This model assumes random fluctuation around an average population size; the author does not consider stochastic and environmental effects on the viability of small populations. A second conclusion is that abundant species will, on average, decrease over time. Sites selected for the abundance of an indicator may not, over the long term, actually be the sites with the largest populations. The third conclusion is that the vegetation in permanent plots selectively placed in areas of community homogeneity will, over time, become more heterogenous as small scale disturbances create the patches within the plots that were avoided with initial placement.

design, indicators, objectives, permanent plots, succession, predicting change, ecological models, long-term ecological monitoring.

947. Pamo, E. T.; Pieper, R. D.; Beck, R. F. 1991. **Range condition analysis: comparison of two methods in southern New Mexico desert grasslands**. Journal of Range Management. 44: 374-378.

community-level, field techniques, technique comparison, rangeland, herbaceous species, grassland, community change.

948. Panzer, K. F.; Rhody, B. 1981. **Applicability of large-scale aerial photography to the inventory of natural resources in the Sahel of Upper Volta**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 287-299.

landscape-level, inventory, general examples, pattern, ecosystem management, inventory, large-scale monitoring, integrated monitoring, remote sensing, aerial photography.

949. Park, G. N. 1973. **Point height intercept analysis**. New Zealand Journal of Botany. 11: 103-114.

field techniques, point intercept, cover, heights, community-level, community composition.

950. Parker, I. 1983. **Effective reporting of monitored changes and trends**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 664-667.

The author examines monitoring and reporting within the context of a Forest Plan or other monitoring plan in which the purpose of monitoring is to determine if predicted levels of products, costs, and effects are met under current management. Monitoring is hierarchical with the objectives varying by level. At the Forest Service District level, specific projects are monitored by collecting site-specific biological and physical data to evaluate the effects of specific management. At regional and national levels, cost and rate of implementation of management are monitored. A decision tree is presented for determining monitoring and reporting frequencies based on the level of deviation from expected products or conditions, and the consequences of the effect. Elements of a monitoring plan are outlined. A list of recommendations for realizing monitoring opportunities and negating barriers to implementing good monitoring is presented, specifically addressing resistance to data collection and the traditional reliance on professional judgement. Qualities of effective reporting include: 1) communication with the decision-maker; 2) inclusion of summary information; 3) display of supporting data; and 4) presentation of several corrective alternatives.

monitoring and management, agency guidance and policy, agency plans, objectives, monitoring overviews, data management.

951. Parker, K. W.; Harris, R. W. 1959. **The 3-step method for measuring condition and trend of forest ranges: a resume of its history, development and use**. Techniques and methods of measuring understory vegetation. Tifton, GA: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 55-69.

Step 1 is the collection of field data from permanent transects along which are completed 100 loop frames of 3/4in, 100 points (noting nearest plant), a vigor assessment, a 1/100ac density plot, classification of age and form of shrubs, and an estimation of current erosion. Step 2 is the summary of the field data onto a scorecard, providing a rating of the site. Step 3 is the establishment of permanent photopoints. Cover values produced by the loop method were compared to other methods. Line intercept gave 2% cover, point intercept 9%, toe point 13%, and loop 15%. Correlation between methods was consistent at different sites and with different observers. For the loop method, the differences between observers was insignificant 16 out of 26 times. Along permanently staked lines, 75% of the loop readings were identical between readings.

field techniques, cover, community structure, community composition, rangeland, canopy cover, loop frames, point intercept, line intercept, photopoints, technique comparison, permanent plots, observer variability, grassland.

952. Parker, K. W.; Savage, D. A. 1944. **Reliability of the line interception method in measuring vegetation on the southern Great Plains**. Journal of The American Society of Agronomy. 36: 97-110.

community-level, grassland, community composition, field techniques, cover, line intercept, herbaceous species.

953. Paruelo, J. M.; Lauenroth, W. K. 1996. **Relative abundance of plant functional types in grasslands and shrublands of North America**. Ecological Applications. 6(4): 1212-1224.

functional groups, landscape patterns, community comparisons, community-level, landscape-level, shrub grassland, grassland.

954. Pase, C. P. 1981. **Community structure analysis-- a rapid, effective range condition estimator for semi-arid ranges**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 425-430.

Community Structure Analysis (CSA) computes an importance value based on cover, density, and frequency. The method utilizes a pace transect. Every 2 paces, a 5x10cm microplot is placed for estimation of cover, a total of 100 microplots. Species occurrence in these microplots is also the basis for the frequency value. Density is estimated using a circular meter^2 plot placed around every tenth microplot. Complete field directions are given for monumentation and implementation, including example field sheets. Tests were done with three observers, the steel survey tape remaining in place. In spite of the lack of relocation error, cover estimates ranged from 12% to 17%, density from 26.6 to 37.5 plants/m^2, and frequency from 83% to 90% among the three observers.

rangeland, monitoring examples, inventory, design, sampling design, cover, density, field techniques, frequency, observer variability, ocular estimation.

955. Patil, G. P.; Johnson, G.; Grigoletto, M. 1996. **Covariate-directed sampling for assessingspecies richness**. In: Mowrer, H. T.; Czaplewski, R. L.; Hamre, R. H., eds. Spatial accuracy assessment in natural resources and environmental sciences: second international symposium; 1996 May 21-23; Ft. Collins, CO. Gen. Tech. Rep. RM-GTR-277. Ft. Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 569-576.

community-level, species richness, species lists, large-scale monitoring, general examples.

956. Patil, G. P.; Rao, C. R., eds. 1994. **Environmental statistics**. Rao, C. R., general ed. Handbook of statistics, vol. 12. New York, NY: Elsevier. 916 p.

This book brings together more than 20 papers on environmental sampling and analysis. Many of them are directed at biomonitoring in aquatic systems, but several papers are directly pertinent to vegetation sampling. A chapter titled "Ecological statistics" provides an overview of those techniques especially useful in examining the relationships between animals, plants, and their environment. Single species problems, community analysis, and a discussion about observational and experimental studies in ecology are included. Another chapter describes several types of adaptive sampling, where a simple or stratified random model is replaced with one in which units containing a rare event are purposefully selected. Two chapters address forest resources, one on forest biometrics and another on ecological diversity and forest management, which includes a review of diversity measures. Finally a chapter is included on environmental remote sensing and GIS applications.

analysis, statistics overview, detecting change, sampling design, experimental design, cluster sampling, forest, species diversity, diversity indices, similarity measures, remote sensing, ecosystem management, biodiversity, multivariate analysis, community composition, community change.

957. Patil, G. P.; Rosenzweig, M. L., eds. 1979. **Contemporary quantitative ecology and related ecometrics**. Patil, G. P., ed. Statistical ecology series, vol. 12. Burtonsville, MD: International Cooperative Publishing House. 691 p.

The Statistical Ecology Series contains thirteen volumes published between 1971 and 1979. This volume contains the following papers that may be applicable to monitoring situations: "Analysis of species occurrences in community, continuum and biomonitoring studies," "Current approaches to the non-linearity problem in vegetation analysis," "Applications of eigenvector analysis in the resolution of spectral pattern in spatial and temporal ecological sequences," and "A bibliography of selected books on quantitative ecology and related ecometrics."

community-level, biodiversity, species diversity, similarity measures, analysis, multivariate analysis.

958. Patil, G. P.; Taillie, C. 1982. **Diversity as a concept and its measurement**. Journal of The American Statistical Association. 77: 548-567.

community-level, species diversity, diversity indices.

959. Patton, D. R. 1987. **Is the use of "management indicator species" feasible?** Western Journal of Applied Forestry. 2(1): 33-34.

While plant indicator species have been used successfully to monitor vegetation changes, the efficiency of using mobile terrestrial species is yet unproven. Because these organisms can move between treatment areas, several management actions occurring in a general area may create interactions that mask the indicator value of the species for a particular management action. Management indicator species are intended to be those whose changes indicate the effect of management on other species, but this may not be valid; there is little research. In some cases, it may be easier to measure the habitat parameter rather than the response of an indicator. If an indicator is needed, the author suggests that plants are more effective than animals. The following program is recommended as an alternative to the management indicator species approach: 1) map acreage and location of vegetation by successional stage; 2) develop an animal species list for each vegetation type categorized by successional stages; 3) monitor change in acreages; and 4) monitor species of concern directly.

landscape-level, community-level, habitat management, indicators, landscape change, vegetation mapping, monitoring and management, ecosystem management.

960. Pavlik, B. M. 1987. **Autecological monitoring of endangered plants**. In: Elias, T. S., ed. Conservation and management of rare and endangered plants. Sacramento, California: The California Native Plant Society: 385-390.

rare species, monitoring overviews, field techniques, demographic techniques.

961. Payne, G. F. 1974. **Cover-weight relationships**. Journal of Range Management. 27: 403-404.

field techniques, cover, weight estimate, production, rangeland.

962. Pearse, K. 1935. **An area list method of measuring range plant populations**. Ecology. 16: 573-579.

field techniques, cover, charting.

963. Pearson, H. A.; Sternitzke, H. S. 1974. **Forest-range inventory: a multiple-use survey**. Journal of Range Management. 27: 404-407.

field techniques, cover, ocular estimation.

964. Pechanec, J. F. 1941. **Sampling errors in range surveys of sagebrush-grass vegetation**. Forestry. 39(1): 52-54.

sampling design, design, shrubland, grassland, shrub grassland, shrub, herbaceous species, observer variability, rangeland.

965. Pechanec, J. F.; Stewart, G. 1940. **Sagebrush-grass range sampling studies: size and structure of sampling unit**. Journal of the American Society of Agronomy. 32: 669-682.

The authors sampled a large area in an sagebrush/mixed grass-forb range in small contiguous units that could be combined into a number of different quadrat sizes and shapes. Long narrow plots were the most efficient for estimating production.

design, field techniques, precision, production, shrub grassland, plot dimensions, rangeland.

966. Peet, R. K. 1974. **The measurement of species diversity**. Annual Review of Ecology and Systematics. 5: 285-307.

community-level, species diversity, species lists, diversity indices.

967. Peet, R. K.; Glenn-Lewin, D. C.; Walker-Wolf, J. 1983. **Prediction of man's impact on plant species diversity - a challenge for vegetation science**. In: Holzner, W.; Werger, M. J. A.; Ikusima, I., eds. Man's impact on vegetation. The Hague: Junk: 41-54.

objectives, monitoring and management, predicting change, ecological models, exotics, disturbance, species diversity.

968. Peet, R. K.; Knox, R. G.; Case, J. S.; Allen, R. B. 1988. **Putting things in order: the advantages of detrended correspondence analysis**. American Naturalist. 131: 924-934.

analysis, multivariate analysis.

969. Peroni, P. A.; Abrahamson, W. G. 1985. **A rapid method for determining losses of native vegetation**. Natural Areas Journal. 5: 20-24.

monitoring examples, field techniques, ecological monitoring programs, natural areas, special sites, exotics, succession.

970. Perry, J. N. 1986. **Multiple-comparison procedures: a dissenting view**. Journal of Economic Entomology. 79: 1149-1155.

analysis, multiple comparisons.

971. Perry, J. A.; Schaeffer, D. J.; Herricks, E. E. 1987. **Innovative designs for water quality monitoring: are we asking the questions before the data are collected?** In: Boyle, T. P., ed. New approaches to monitoring aquatic ecosytems. ASTM STP940. Philadelphia, PA: American Society for Testing and Materials: 28-39.

The author differentiates between surveillance and monitoring. Surveillance data can be collected in the absence of an identified need for decision making; monitoring is used to evaluate management. When monitoring data is insufficient for decision-making, the response has often been to collect additional samples. A better approach is to more precisely define the goals of monitoring and design more specific, efficient techniques for data collection. An approach is presented in this paper in which the questions proposed by the information users (managers) are translated into quantifiable objectives, for which appropriate monitoring designs are developed. The authors present two water quality scenarios, one in which the data collected for monitoring were inconclusive and conflicting, and another that utilized the planning process described here.

monitoring overviews, adaptive management, monitoring and management, objectives, sampling design, design, indicators.

972. Persson, O. 1971. **The robustness of estimating density by distance measurements**. In: Patil, G. P.; Pielou, E. C.; Waters, W. E., eds. Sampling and modeling biological populations and populations dynamics. Patil, G. P., series ed. Statistical ecology, vol. 2. University Park, PA: Pennsylvania State University Press: 175-187.

This paper quantifies the bias of distance measures for measuring density.

field techniques, distance methods, density, nearest neighbor.

973. Peterken, G. F.; Backmeroff, C. 1988. **Long-term monitoring in unmanaged woodland nature reserves**. NCC Research and Survey in Nature Conservation 11. Peterborough: Nature Conservancy Council.

monitoring examples, field techniques, long-term ecological monitoring, woodland, tree, natural areas, special sites.

974. Peterken, G. F.; Jones, E. W. 1987. **Forty years of change in Lady Park Wood: the old-growth stands**. Journal of Ecology. 75: 477-512.

monitoring examples, long-term ecological monitoring, woodland, forest, tree.

975. Peterman, R. M. 1990. **The importance of reporting statistical power: the forest decline and acidic deposition example**. Ecology. 71: 2024-2027.

The example of decline in forest growth rates in response to acidic deposition is used to illustrate the importance of statistical power. Researchers have been unable to find convincing evidence to reject the null hypothesis of no effect from acidic deposition. What has not been reported, however, is the power of these studies, the probability of detecting an effect of a given magnitude. Power is often low in ecological studies because of the variable nature of the data and the small sample size of many studies. The author cites one study on whales in which 50% declines would have only a 69% chance of being detected. The failure to report power is especially problematic in the natural resource management field. Decision-makers may not be aware that failure to reject the null hypothesis does not necessarily mean that the null hypothesis is true but that the power of the monitoring design may simply be too low to detect an effect. Failure to consider power implies that there is no cost associated with a Type II error (incorrectly concluding that there is no effect from, for example, acid deposition). If Type II errors are expensive, the burden of proof should be shifted, especially when high power is difficult to achieve. In approving new chemicals, for example, the burden of proof is on industry to show that the substance is not harmful. This is because the costs of a Type II error (impacts on health if the substance turns out to be harmful) is high relative to the costs of a Type I error (the loss of a potentially useful product and the associated research and development costs borne by industry). A similar approach could be applied to environmental issues.

Type I and Type II errors, design, sampling design, detecting change, power, precision, sample size, statistical interpretation.

976. Peterman, R. M. 1990. **Statistical power analysis can improve fisheries research and management**. Canadian Journal of Fisheries and Aquatic Sciences. 47: 2-15.

Although the subject matter is fisheries management, this paper has important implications for vegetation sampling. It argues the importance of power analysis in detecting undesirable changes in the resource. Concepts of statistical power are summarized and illustrated with examples. A review of existing monitoring studies illustrates that power to detect change is usually unacceptably low. The author suggests that Type II errors are often more expensive than Type I errors (e.g., crashes of fish populations), thus the two error rates should be, at a minimum, set to equal levels. Even better, the burden of proof should shift from detecting impact to demonstrating no impact is occurring.

power, detecting change, sampling design, Type I and Type II errors, precision, objectives, design.

977. Peterson, C. H. 1993. **Improvement of environmental impact analysis by application of principles derived from manipulative ecology: lessons from coastal marine case histories**. Australian Journal of Ecology. 18: 21-52.

Use of the natural range of variation in a biological parameter as a benchmark for determining whether or not an effect is of biological significance may be inappropriate. A sustained change, even when it is within the range of natural variability, may be indicative of an impact.

biological significance, analysis, statistical interpretation, community change, aquatic, monitoring and management, natural variability, analysis.

978. Peterson, D. L.; Running, S. W. 1989. **Applications in forest science and management**. In Asrar, G., ed. Theory and applications of optical remote sensing. New York, NY: John Wiley and Sons: 429-473.

Remote sensing of many forest characteristics based on their reflectance values is difficult due to the variability in tree morphology (conifer, broadleaved), canopy density, and ground surface. Several characteristics, however, have been found to be measurable with remote sensing data: leaf area index (the surface area of all leaves above an area of ground), tree height, crown diameter, stand volume and biomass, lignin content, and nitrogen content. Classification of pixels to forest/nonforest types can be used to measure change over time, defoliation by gypsy moths, and compliance with logging plans. Remotely sensed classification of forests is also used in two-stage sampling plans to first stratify the area that will be sampled with ground plots.

tree, sampling design, design, remote sensing, Landsat, vegetation mapping, forest, production, crown diameter, biomass, large-scale monitoring, two-stage sampling.

979. Peterson, D. L.; Silsbee, D. G.; Schmoldt, D. L. 1994. **Developing inventory and monitoring programs in national parks: a planning approach**. Natural Resources Rep. Washington, DC: U.S. Department of Interior, National Park Service, Cooperative Park Studies Unit, University of Washington.

monitoring examples, inventory, baseline monitoring, national parks, special sites, monitoring overviews, objectives.

980. Peterson, R. G. 1977. **Use and misuse of multiple comparison procedures**. Agronomy Journal. 69: 205-208.

analysis, multiple comparisons.

981. Pettit, N. E.; Froend, R. H.; Ladd, P. G. 1995. **Grazing in remnant woodland vegetation: changes in species composition and life form groups**. Journal of Vegetation Science. 6: 121-130.

Permanent 10x10m plots (35 ungrazed and 21 grazed) were used to evaluate the effects of grazing on functional groups of plants. Plants were grouped by life form (native shrub, native herb, native annuals, native grasses, exotic annual herb, exotic annual grasses) and by reproductive strategies (seeders, resprouters, and facultative). Detrended correspondence analysis illustrated that vegetation composition split into two distinct groups representing grazed and ungrazed situations. The effect of grazing on species diversity and evenness was also illustrated. Time series ordination was used to explore the changes that occurred on excluded plots over three years. Use of functional groups allowed detection of patterns in response to grazing (primarily the increase in annuals and exotics) that were masked in analysis of complete floral composition.

community composition, community change, multivariate analysis, analysis, detecting change, permanent plots, woodland, functional groups, community-level, time series.

982. Phillips, D. J. H. 1980. **Quantitative aquatic biological indicators**. London, England: Applied Science Publishers, LTD. 488 p.

aquatic, indicators, landscape-level.

983. Phillips, J. D. 1985. **Measuring complexity of environmental gradients**. Vegetatio. 64: 95-102.

analysis, multivariate analysis, scale, community-level, community composition, landscape-level, pattern, species diversity.

984. Pickart, A. J. 1991. **The evolution of a rare plant monitoring program: a case study at the Lanphere-Christensen Dunes Preserve**. Natural Areas Journal. 11(4): 187-189.

rare species, monitoring examples, objectives, ecological monitoring programs, special sites, protected areas.

985. Pickart, A. J.; Stauffer, H. B. 1994. **The importance of selecting a sampling model before data collection: an example using the endangered Humboldt milk-vetch (*Astragalus agnicidus* Barneby)**. Natural Areas Journal. 14: 90-98.

design, sampling design, rare species, performance.

986. Pickett, S. T. A. 1991. **Long-term studies: past experience and recommendations for the future**. In Risser P. G., ed. Long-term ecological research: an international perspective. Scientific Committee on Problems of the Environment (SCOPE) 47. New York, NY: John Wiley and Sons: 71-85.

Drawing from the publication by Strayer and others (1986), this chapter reviews the characteristics of long-term studies, and attributes of successful studies and their motivations. Recommendations are presented for planning and executing future long-term studies. It is suggested that all studies should begin with a conceptual model and that if it is not possible to construct a tentative model then experimentation is premature. Broader spatial extent is needed in studies, especially to determine phenomena and patterns that occur at landscape or regional scales. Several recommendations are made related to methodologies.

long-term ecological monitoring, monitoring examples, ecological monitoring programs, objectives, ecological models.

987. Pickett, S. T. A. 1987. **The role of theory in permanent plot studies**. Permanent Plotter: A Newsletter of The Ecological Society of America. 1: 5-6.

Designing permanent plot studies to address an ecological theory greatly enhances their usefulness. In many cases, long-term studies were implemented with an underlying understanding (theory) of vegetation dynamics, but these are not always explicitly stated, reducing the interpretive value of the study for later investigators. Some examples of theories which have guided establishment of permanent plots in the past are the Clementsian concept of climax and Egler's theory of initial floristic establishment in controlling succession.

permanent plots, long-term ecological monitoring, ecological models, succession, community change, community-level.

988. Pickett, S. T. A.; White, P. S., eds. 1985. **The ecology of natural disturbance and patch dynamics**. Orlando, Florida: Academic Press. 472 p.

landscape-level, patch dynamics, succession, disturbance, landscape change, community-level, community change.

989. Pickford, G. D.; Stewart, G. 1935. **Coordinate method of mapping low shrubs**. Ecology. 16: 257-261.

A method of mapping shrubs using an easily constructed instrument is described. Four stakes, each outfitted with an clamp that can be adjusted for height, are placed at the corners of a plot 4ft wide and any desired length. Two flat steel surveying tapes are clamped to the stakes, forming the lengths of the plot. A lightweight metal crossbar, slightly longer than 4ft and graduated in feet and subunits is balanced on the surveying tapes. The intercept of the shrub canopy on the crossbar is measured at set distances along the surveying tape and a map drawn on gridded paper.

field techniques, density, demographic techniques, shrub grassland, shrubland, charting, canopy cover, tools, cover, shrub.

990. Pickup, G. 1989. **New land degradation survey techniques for arid Australia- problems and prospects**. Australian Rangeland Journal. 11: 74-82.

The author proposes a monitoring method to separate land degradation from natural landscape variability and short-term change due to weather. Changes in relative vegetation cover

over various spatial and temporal scales would be coupled to models of distribution of grazing intensity. These cover measures are amenable to remote sensing techniques.

remote sensing, detecting change, disturbance, canopy cover, vegetation mapping, Landsat, landscape-level, natural variability, ecological models, cover.

991. Pickup, G.; Bastin, G. N.; Chewings, V. H. 1994. **Remote-sensing-based condition assessment for nonequilibrium rangelands under large-scale commercial grazing**. Ecological Applications. 4: 497-517.

landscape-level, landscape change, vegetation treatments, community-level, community change, succession, rangeland, grassland, shrubland, shrub, herbaceous species, remote sensing.

992. Pickup, G.; Chewings, V. H.; Nelson, D. J. 1993. **Estimating changes in vegetation cover over time in arid rangelands using Landsat MSS data**. Remote Sensing of the Environment. 43: 243-264.

Landsat MSS imagery has been available for most arid land areas in Australia since 1979, with irregular coverage to 1972. This historic value, coupled with its relatively low cost (compared to SPOT and Landsat TM data) makes Landsat MSS attractive for long-term monitoring. In this paper, a vegetation index approach is used which provides information on relative amounts of cover and cover change. An index using MSS Bands 4 and 5 was found most effective. Ground-based radiometric data from 206 targets ($1m^2$) were used to investigate the response of the index to pure values of rock, soil, and vegetation types. Aircraft-mounted sensors were used to determine how the index performed at the MSS pixel scale over a wide range of soil and vegetation types, and comparatively at different times in the season. A method for adjusting the MSS-derived index to account for various satellite types, sun angles, and atmospheric conditions is presented. The method was tested on 700 sites where vegetative cover had been measured from aerial photographs. Correlations ranged from 78% to 88%.

remote sensing, Landsat, MSS, TM, vegetation mapping, cover, large-scale monitoring, rangeland, landscape-level, landscape change, detecting change, aerial photography.

993. Pielou, E. C. 1984. **The interpretation of ecological data. A primer on classification and ordination**. New York, NY: Wiley. 259 p.

This book is one of several standard texts on multivariate analysis of community data. Explanations of the methodologies are explained in both mathematical and textual form. Examples are created from short artificial data sets so the results can be easily visualized and understood. Exercises with answers are included.

analysis, multivariate analysis, statistics overview.

994. Pielou, E. C. 1966. **Species-diversity and pattern-diversity in the study of ecological succession**. Journal of Theoretical Biology. 10: 370-383.

community-level, community change, diversity indices, species diversity, succession.

995. Pieper, R. D. 1973. **Measurement techniques for herbaceous and shrubby vegetation**. Las Cruces, NM: New Mexico State University, Department of Animal, Range, and Wildlife Sciences. 190 p.

This unpublished document has been fairly widely circulated and can often be found in libraries in photocopied and bound form. It covers the range of techniques used to sample rangeland vegetation. Chapters include: "Sampling theory and techniques," which covers concepts of normal distribution, standard error and simple analysis techniques; "Measurement of vegetation attributes," which addresses primarily measurements of production; "Methods for determining area or cover," covering point methods, line intercept, loop, and ocular estimation; "Methods for determining number," including quadrat and distance techniques; "Methods of measuring utilization;" "Aerial photo interpretation and mapping;" and "Vegetation mapping." All methods are referenced for original source, and illustrated with examples. The document is especially valuable because it describes older methods, used in the 1940s through 1960s, aiding the understanding of methods cited in older literature.

field techniques, vegetation mapping, rangeland, shrubland, shrub grassland, grassland, density, distance methods, basal area, canopy cover, charting, cover classes, line intercept, loop frames, ocular estimation, point frames, point intercept, variable plots, biomass, performance, production, weight estimate, aerial photography, utilization, shrub, herbaceous species.

996. Pieper, R. D. 1990. **Overstory-understory relations in pinyon-juniper woodlands in New Mexico**. Journal of Range Management. 43(5): 413-415.

general examples, woodland, field techniques, production, cover, biomass, canopy cover, community structure, community-level, rangeland.

997. Pieper, R. D. 1988. **Rangeland vegetation productivity and biomass**. In: Tueller, P. T., ed. Vegetation science applications for rangeland analysis and management. Boston: Kluwer Academic Publishers: 449-446.

This chapter summarizes the methods of measuring rangeland production: harvest methods, precipitation-based models, capacitance meters, the beta attenuation technique, and cover and dimension analysis (identifying allometric relationships between biomass and a more easily measured parameter). The uses of productivity measures in estimating range carrying capacity and describing community composition is discussed. The chapter is well-referenced.

field techniques, community-level, biomass, production, performance, rangeland, community composition.

998. Pierce, W. R.; Eddleman, L. E. 1970. **A field stereo photographic technique for range vegetation analysis**. Journal of Range Management. 23: 218-220.

A Hasselblad large format camera (55mm, 75 degree field of view) was used to make color stereo photographic pairs of a 1x1m frame, divided into twenty-five 20x20cm frames. The camera was suspended 5ft above the ground. The second exposure was offset 18cm from the first. In addition, two oblique frames were taken from the bottom of the plot to photograph smaller understory species. Field notes included a record of all species occurring in each subframe. Accuracy of lab identifications was checked by comparing field notes with lab interpretation by an independent observer who was familiar with the vegetation type but not the plots. Accuracy of species identification was 95%.

field techniques, cover, photoplots, canopy cover, tools, observer variability.

999. Pierce, W. R.; Eddleman, L. E. 1973. **A test of stereophotographic sampling in grasslands**. Journal of Range Management. 26: 148-150.

Forty-two $1m^2$ stereo photographic plots were compared to 400 plots ($1ft^2$) in which cover was estimated. Two types of cameras were used for each photoplot: a Hasselblad 70mm film and a Nikkon 35mm. Cover was estimated using the intersection of a grid on the photograph and a pocket stereoscope. Photographic interpretation underestimated cover for most graminoid species and those with withered leaves compared to field measurements. Tufted species and broadleaf herbs were estimated similarly by the two techniques. The 70mm format provided better photographs because of better resolution, larger frame size, and better depth of field. The use of a ring-strobe light to augment natural light reduced shadows and increased the accuracy of the species identifications.

field techniques, photoplots, cover, canopy cover, tools, technique comparison, ocular estimation.

1000. Pitt, D. G.; Glover, G. R. 1993. **Large-scale 35-mm aerial photographs for assessment of vegetation-management research plots in eastern Canada**. Canadian Journal of Forest Research. 23(10): 2159-2169.

field techniques, photopoints, aerial photography, forest.

1001. Pitt, D. G.; Glover, G. R.; Jones, R. H. 1996. **Two-phase sampling of woody and herbaceous plant communities using large-scale aerial photography**. Canadian Journal of Forest Research. 26: 509-524.

aerial photography, two-stage sampling, succession, community-level, community structure, cover.

1002. Platts, W. S. 1990. **Managing fisheries and wildlife on rangelands grazed by livestock**. Reno, NV: Nevada Department of Wildife. 365 p.

This guide is primarily concerned with management of streams and riparian areas. A chapter on "Inventory and monitoring" contains suggested methodologies for monitoring riparian areas, some of them vegetation-based. Additional chapters on GIS mapping, aerial photo interpretation, and estimation of utilization are also helpful. The most valuable and unique parts of this guide, however, are an overview of the legal mandates for managing these areas, and a chapter on working with the Forest Service, Bureau of Land Management, and ranchers. These two chapters can be useful in understanding the direction given by Congress, the general goals of the two land management agencies, and the goals of a federal land user. This understanding is critical for the development of objectives that are not only ecologically valid, but also account for the politics of the agency and the use of the land by people.

agency guidance and policy, monitoring and management, objectives, aerial photography, GIS, riparian, utilization.

1003. Platts, W. S.; Armour, C.; Booth, G. D.; Bryant, M.; Bufford, J. L.; Cuplin, P.; Jensen, S.; Lienkaemper, G. W.; Minshall, G. W.; Monsen, S. B.; Nelson, R. L.; Sedell, J. R.; Tuhy, J. S. 1987. **Methods for evaluating riparian habitats and applications to management.** Gen. Tech. Rep. INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 177 p.

This technical reference provides extensive guidance for an abundance of methods for inventory and monitoring of riparian areas, including vegetation measurements, classification and description of soils, remote sensing techniques, stream bed and bank measurements, mapping of organic woody debris, and using historical records. While some of the methodologies are germane to terrestrial vegetation sampling, the most widely applicable chapter is the one on sampling. Provided is a clear, brief, and lucid description of several sampling designs (simple random, stratified random, cluster, and two-stage), complete with resource-related examples.

community composition, community structure, cover, riparian, wetland, canopy cover, aerial photography, cluster sampling, random sampling, stratified sampling, two-stage sampling, soils, sampling design, community-level.

1004. Podani, J.; Czaran, T.; Bartha, S. 1993. **Pattern, area and diversity: the importance of spatial scale in species assemblages**. Abstracta Botanica. 17: 37-51.

landscape-level, scale, pattern, species lists, species diversity, biodiversity.

1005. Poissonet, P. S.; Daget, P. M.; Poissonet, J. A.; Long, G. A. 1972. **Rapid point survey by bayonet blade**. Journal of Range Management. 25: 313.

A blade 65cm high, 4.5cm wide, and 2mm thick, sharpened along one edge, can provide accurate and rapid measurements of point interception along the sharpened edge. A trained observer can complete 350 sightings a day. These bayonet readings result in much smaller deviations between observers compared to needle point frames.

field techniques, cover, canopy cover, point frames, point intercept, observer variability, technique comparison.

1006. Poissonet, P. S.; Poissonet, J. A.; Bodron, M. P.; Long, G. A. 1973. **A comparison of sampling methods in**

dense herbaceous pasture. Journal of Range Management. 26: 65-67.

Estimates of frequency and cover were compared between the following sampling units in a perennial grassland: needle points, points sighted with a meter stick, bayonet points, presence in line transects of 25cm segments along a 64m line, and ocular estimation in plots (an area of $0.25m^2$ in five different shapes). Points measured all vegetation layers intercepted from the canopy to the ground surface. In each sampling area, forty 100x25cm plots were harvested and sorted by species. Frequency values increased relative to needle points in the order of sampling units given above. Using the needle point intercept method as the reference, line intercept and plots gave dramatically higher cover values at low cover values (<10%). Point intercept showed a nearly linear relationship to biomass in that relative cover measures (the percent of hits on a particular species compared to the number of hits on vegetation overall) compared directly to relative biomass (e.g., 75% relative cover was approximately equal to 75% relative biomass). The authors stressed the importance of very sharp pins for accurate measurement of cover by points. For each of the other methods, a characteristic curve could be developed relating the frequency measure and contribution of interception ("relative species volume" or the percentage of hits for each species out of the total number of multiple hits). By using these curves, the percent composition can be estimated quickly by initially using one of the faster methods of measuring frequency, then relating it to the contribution of interception, and thus to relative biomass.

field techniques, cover, canopy cover, point intercept, line intercept, technique comparison, ocular estimation, community composition, biomass, herbaceous species.

1007. Pope, R. B. 1960. **Ocular estimation of crown density on aerial photos**. Forestry Chronicle. 36: 89-90.

Two methods are suggested for estimating crown cover on photos, and the author suggests that both be used to provide more confidence in the estimation. The "tree cramming" method involves moving trees ocularly from less crowded quadrants to the more crowded ones to try to fill in holes and create a continuous canopy in the "crammed" quarters. In the second method, existing crowns are counted and then the number of imaginary trees of similar size needed to fill in the remainder of the photograph plot are counted to determine percent crown cover. This method is most accurate when crowns are similar in size.

coniferous forest, canopy cover, ocular estimation, aerial photography, remote sensing, crown diameter.

1008. Potvin, C.; Roff, D. A. 1993. **Distribution-free and robust statistical methods: viable alternatives to parametric statistics**. Ecology. 74: 1617-1628.

analysis, nonparametric statistics, parametric statistics.

1009. Potvin, M. A.; Harrison, A. T. 1984. **Vegetation and litter changes of a Nebraska Sandhills prairie protected from grazing**. Journal of Range Management. 37: 55-58.

This paper reports on a study established to monitor the initial 4 years of vegetation change in a prairie plant community excluded from livestock grazing. Fifteen $4m^2$ permanent macroplots were randomly established. A single $1m^2$ quadrat within each macroplot was selected for production measurement in September for 4 consecutive years, a different quadrant of the macroplot each year. Production was measured by clipping, separating by species, drying, and weighing. The authors noted that C3 grasses would be underestimated by sampling at this time of year. Biomass by species was determined for each year, and means compared with a t-test.

permanent plots, grassland, biomass, monitoring examples, field techniques, production.

1010. Poulton, C. E.; Tisdale, E. W. 1961. **A quantitative method for the description and classification of range vegetation**. Journal of Range Management. 4(1): 13-21.

field techniques, rangeland, herbaceous species, shrubland, inventory, community-level, community composition.

1011. Powell, D. S.; Cost, N. D. 1983. **Differentiating real resource change from other concurrent inventory differences**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 541-545.

The author cautions against using repeated inventory values as a measure of real change. Three sources of change may mask or be mistaken for real change: 1) correction of past mistakes; 2) changes in methodology and definitions; and 3) changes in sampling including plot location methodology (simple random to stratified, for example), lost plots, and changes in plot boundaries. These types of changes can have significant impacts on the results. In one example, the difference between two inventories was over a million acres, but when the types of changes described above were accounted for, the real difference was less than half a million acres.

monitoring overviews, monitoring and management, objectives, inventory, detecting change, tree, forest.

1012. Powell, T. M.; Steele, J. H. 1995. **Ecological time series**. New York, NY: Chapman and Hall. 491 p.

analysis, time series, long-term ecological monitoring.

1013. Power, M. E.; Mills, L. S. 1995. **The keystone cops meet in Hilo**. Trends In Ecology and Evolution. 10: 182-184.

Reviews a recent workshop on the concept of keystone species.

landscape-level, indicators.

1014. Press, S. J. 1989. **Bayesian statistics: principles, models and applications**. New York, NY: John Wiley and Sons. 237 p.
analysis, Bayesian statistics, statistics overview.

1015. Pulford, W. J. 1981. **Standardization, coordination and cooperation among resource activities**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 78-84.
A description of the framework of the Bureau of Land Management's integrated inventory process is given. Benefits of an integrated inventory are described, and the development steps discussed. The importance of an inventory plan and its elements are presented.
inventory, integrated monitoring, sampling design.

1016. Pywell, H. R. 1993. **Forest health monitoring with airborne videography**. In: Liebhold, A. M.; Barrett, H. R., eds. Proceedings: spatial analysis and forest pest management. Gen. Tech. Rep. NE-175. Delaware, OH: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 133-141.
remote sensing, video, ecosystem management.

1017. Quinn, J. F.; Robinson, G. R. 1987. **The effects of experimental subdivision on flowering plant diversity in a California annual grassland**. Journal of Ecology. 75: 837-856.
design, sampling design, community-level, plot dimensions, species diversity, landscape-level, fragmentation.

1018. Radcliffe, J. E.; Mountier, N. S. 1964. **Problems in measuring pasture composition in the field. Part II. The effect of vegetation height using the point method**. New Zealand Journal of Botany. 2: 98-105.
field techniques, cover, point intercept, community composition, community-level, grassland.

1019. Radcliffe, J. E.; Mountier, N. S. 1964. **Problems in measuring pasture composition in the field. Part I. Discussion of general problems and some considerations of the point method**. New Zealand Journal of Botany. 2: 90-97.
field techniques, cover, point intercept, community composition, community-level, grassland.

1020. Rader, L.; Ratliff, R. D. 1962. **A new idea in point frames**. Journal of Range Management. 15: 182-183.
field techniques, tools, cover, point intercept, point frames.

1021. Ratliff, R. D. 1990. **Estimating botanical composition by the dry-weight-rank method in California's annual grasslands**. Res. Note PSW-410. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 5 p.
The standard for estimating botanical composition is the percentage of dry weight by species. One alternative to clipping, drying, and weighing vegetation is the dry-weight-rank (DWR) method, in which the three species contributing the most to the biomass in a sampling unit are determined by sight. These are then summarized by calculating the proportion of all sampling units in which a species ranks 1, 1, or 3, and summing that proportion times a coefficient for each of the three ranks to estimate the percent dry weight composition for the species. With some modifications, this approach has been successfully applied in several grassland types. In this paper, the method is tested in California annual grasslands. Two existing large data sets of clipped plots, one spanning 8 years and the other 20 harvest dates over the course of a growing season, were used to compare clipped values to the DWR estimates. Two published coefficient series were used, as well as coefficients directly calculated from the data. Only a few of the comparisons of estimated with actual clipped composition were significantly different. The authors also found that the standard coefficients of 0.70, 0.20, and 0.10 for each rank performed adequately, thus calculating new coefficients for each site is probably unnecessary.
community-level, community composition, grassland, biomass, weight estimate, dry-weight-rank, field techniques, production.

1022. Ratliff, R. D. 1995. **Rangeland alpha diversities: Harvey Valley, Lassen National Forest, California**. Great Basin Naturalist. 55(1): 46-57.
community-level, rangeland, species diversity, community composition.

1023. Ratliff, R. D. 1993. **Sierra Nevada meadows: species alpha diversity**. Res. Note PSW-RN-415. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 5 p.
Alpha diversity is the within-site diversity of a community--the populations co-occurring at a specific time in a specific space. Monitoring diversity usually begins with an estimate of alpha diversity, but such published estimates are rare. This paper provides estimates of alpha diversity for 82 mountain meadow sites comprising 14 site classes in California. On each, species lists were prepared and frequency was estimated based on 300 nearest shoot to point intercepts. This method was chosen because even in relatively dense meadow vegetation, only 4.4% of all basal hits (4766 points total) were on a plant. Average distance from point to nearest shoot was about 6mm. Species frequencies on an additional 12 sites were sampled using 100 randomly located 10x10cm quadrats. Margalef's diversity index was selected because it stresses the species richness (number of species) aspect of diversity, and Simpson's index was selected because it stresses the evenness (the relative abundances of species) component. Neither are based on any

underlying assumptions about species abundance distributions. The values of diversity indices did not relate to ecological state or meadow health, but there was a general trend of lowest diversity at the extremes of the moisture gradient. For monitoring diversity, quadrat and point methods both had drawbacks. The quadrat method fails to estimate actual abundance, because the distribution of the species at the site strongly affects the frequency. Use of a standard plot size results in some species being undetected and others occurring with 100% frequency. The point to nearest shoot method was efficient for estimating the number of species and their relative importance. It does not, however, provide a reliable estimate of frequency because the plot size is actually variable (the distance to the nearest shoot), and thus is biased toward larger and isolated individuals. Species lists may be the simplest approach to monitoring diversity.

monitoring examples, field techniques, cover, point intercept, community-level, biodiversity, diversity indices, species richness, species diversity, species lists, grassland, meadow, frequency, variable plots, basal area, nearest neighbor.

1024. Ratliff, R. D. 1993. **Viewpoint: trend assessment by similarity-- a demonstration.** Journal of Range Management. 46: 139-141.

Community composition (here described by cover measured with line intercept) can be compared between years by using a coefficient of similarity such as the Dice, Jaccard, Ochiai, or Sorensen's coefficient. These coefficients range from 0 (indicating a complete lack of similarity) to 1 (complete similarity). Community composition on a site can also be compared to a desired composition, either the potential natural community (PNC) or some community defined by objectives. Graphs of a few to several years of the coefficient of similarity for the existing community compared to the desired can provide a visual portrayal of trend.

community composition, multivariate analysis, trend analysis, similarity measures, community change, detecting change, community-level, analysis, cover, line intercept, field techniques.

1025. Ratliff, R. D.; Mori, S. R. 1993. **Squared Euclidean distance: a statistical test to evaluate plant community change.** Res. Note PSW-416. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 4 p.

Squared Euclidean (SQE) distance between sampling units can be compared for random sampling units collected in a given year (intracluster distances). The SQE can also be used to compare to the distances between these clusters and another set of randomly sampled units (intercluster distances). The hypothesis that the mean intracluster distances and the mean intercluster distances are equal (no community change) can be tested for significance. Confidence intervals of the size and precision of the estimate mean distances can also be calculated. A worked example, starting with the sampling units and species, is presented.

community composition, community change, multivariate analysis, statistical interpretation, confidence intervals, similarity measures, community-level, analysis, detecting change.

1026. Ratliff, R. D.; Westfall, S. E. 1989. **Monitoring plant community change: an application of quadrat classification and discriminant analysis.** Vegetatio. 80: 1-9.

community-level, community change, detecting change, multivariate analysis.

1027. Ratliff, R. D.; Westfall, S. E. 1973. **A simple stereo photographic technique for analyzing small plots.** Journal of Range Management. 26: 147-148.

With a stereo adapter, a frame taken with a single camera will contain stereo pairs. A square-foot plot was photographed with a single camera from about 48in above the ground. This gave a scale of about 1:7. Individuals familiar with the vegetation could accurately assess cover on the photographs using a dot-grid overlay and a pocket stereoscope.

field techniques, cover, photoplots, cover, canopy cover, point intercept.

1028. Reber, C. A.; Ek, A. R. 1982. **Cloquet Forestry Center permanent plot records 1959-1976: status report and plans for remeasurement.** Forestry Resources Staff Paper Series No. 33. Minneapolis, MN: University of Minnesota, Forestry Department. 23 p.

monitoring examples, long-term ecological monitoring, forest, tree, permanent plots.

1029. Reckhow, K. H. 1990. **Bayesian inference in non-replicated ecological studies.** Ecology. 71: 2053-2059.

An example of the type of question addressed by Bayesian statistics is: "What is the probability that the true mean pH in Lake A has increased 10% since 1980" given the data collected. This differs from the question posed in classical statistical test: "What is the probability of measuring a 10% change if there has been in fact no change at Lake A." The p-value resulting from a classical statistical test is not the probability that the null hypothesis is true, but the probability of observing a value as or more extreme as that calculated from the data given that the null hypothesis is true. This approach often overstates the evidence against the null hypothesis. The question of direct interest is the probability that the null hypothesis is true, given the sample evidence, and this is the question addressed by Bayesian analysis. An introduction and an example is provided that demonstrates some of the advantages of Bayesian analysis over classical techniques.

analysis, Bayesian statistics, statistical interpretation, statistics overview, detecting change.

1030. Redd, T. H.; Neale, C. M. U.; Hardy, T. B. 1993. **Use of airborne multispectral videography for the classification and delineation of riparian vegetation**. Proceedings of the 14th biennial workshop on color aerial photography and videography for resource monitoring; 1993 May 25-29; Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 202-211.

Spectral data from two riparian areas were collected using three video cameras, each recording a different narrow band (green, red, and near-infrared). The video data were transferred to a digital format, which assigns each pixel (approximately 50x50cm) a brightness value between 0 and 255. Signatures for each community type were developed by combining ground-based information and operator selection of pixels to include together in a class. Classes of cottonwood, sage, brush, grass, Russian olive, tamarisk, willow, water, sand, rock, and gravel were delineated. Four alternative approaches to computer classification of the remaining pixels were compared (parallelepiped, minimum distance, Mahalanobis distance, and Bayesian distance). These approaches use different algorithms to compare the pixel in question with the available groups and assign membership. Bayesian distance provided the best accuracy (52% to 89% correct placement).

landscape-level, vegetation mapping, riparian, remote sensing, video, aerial photography.

1031. Reich, R. M.; Bonham, C. D.; Remington, K. K. 1993. **Technical notes: double sampling revisited**. Journal of Range Management. 46: 88-90.

Double sampling, usually used in biomass studies, requires estimating the relationship between clipped plots and those that are visually estimated. Two methods are available to express the relationship between clipped and estimated: linear regression and ratio estimation. Regression estimators are best if the line fitting the relationship of clipped to estimated does not pass through the origin; ratio estimators are better for those relationships that pass through or close to the origin. Using 100 plots that were both estimated and clipped, the efficiency of regression and ratio estimators was compared using three methods of estimating variance (classical, jackknife, and bootstrap). The jackknife procedure computes the standard error from among values that are one observation less than the full sample size (e.g., repeated samples of 99 values drawn from the 100). The bootstrap uses a subsample of size K drawn from the 100 sampling units with replacement. In this study, the ratio estimator provided the smallest bias in all trials, but the classical regression estimator provided the best estimate of variance in all trials. For sample sizes over 20, the jackknife and the bootstrap overestimated true variance for both regression and ratio estimators. For sample sizes of 10, however, the jackknife ratio estimator provided the best estimate of the variance.

field techniques, biomass, production, weight estimate, double sampling, randomization tests, jackknife, bootstrap, analysis, sample size.

1032. Reid, E. H.; Pickford, G. D. 1944. **An appraisal of range survey methods**. Journal of Forestry. 42(7): 471-479.

vegetation sampling overview, inventory, rangeland, field techniques.

1033. Reid, W. F.; McNeeley, J. A.; Tunstall, D. B.; Bryant, D. A.; Winograd, M. 1993. **Biodiversity indicators for policy-makers**. World Resources Institute Report. Gland, Switzerland: International Union of Conservation and Nature. 42 p.

landscape-level, ecosystem management, biodiversity, indicators.

1034. Reide, K. 1993. **Monitoring biodiversity: analysis of Amazonian rainforest sounds**. Ambio. 22: 546-554.

monitoring examples, large-scale monitoring, landscape-level, biodiversity.

1035. Rhea, H. T.; McGlothlin, J. W. 1981. **Measurement techniques in the pinyon-juniper woodlands of Nevada**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 485-486.

A system of permanent plots, each 1/10 acre, were established between 1978 and 1980 in the Ely District of the Bureau of Land Management. Plots were placed on a fixed grid of 5000m intersections. Each plot was monumented at the center with a post and rock cairn and referenced to two blazed and painted witness trees. Walking directions to the plot were included on plot datasheets, and the path was marked on mylar overlays on aerial photographs. Within plots, each tree was measured for crown diameter, bole diameter, and height, and permanently marked with an aluminum tag.

monitoring examples, tree, forest, DBH, monumentation, permanent plots, large-scale monitoring.

1036. Rheinhardt, R. 1996. **The role of reference wetlands in functional assessment and mitigation**. Ecological Applications. 6(1): 69-76.

restoration, wetland, objectives, reference areas, predicting change.

1037. Rhody, B. 1981. **Combined forest inventory using 35mm and 70mm aerial photography with an extensive ground survey in *Pinus caribaea* plantations in the Savanna Plain, Venezuela.** In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 471-479.

Aerial photo data were supplemented with ground data collected in a cluster of four relascope points and a single

fixed radius plot in which various timber measures were taken (basal area, volume estimation, height, bark thickness, etc.).

aerial photography, inventory, remote sensing, basal area, DBH, tree, forest, variable plots, density, field techniques.

1038. Rice, E. L. 1967. **A statistical method for determining quadrat size and adequacy of sampling**. Ecology. 48: 1047-1049.

design, sample size, plot dimensions, plot selection, sampling design.

1039. Rice, E.; Penfound, W. T. 1955. **An evaluation of the variable-radius and paired-tree methods in the blackjack-post oak forest**. Ecology. 36: 315-320.

field techniques, forest, technique comparison, variable plots, nearest neighbor, distance methods, density.

1040. Rice, W. R.; Gaines, S. D. 1994. **"Heads I win, tails you lose": testing directional alternative hypothesis in ecological and evolutionary research**. Trends In Ecology and Evolution. 9: 235-237.

In testing the significance of change, a one-tailed test, applicable when the anticipated change is in one direction, is usually substantially more powerful than two-tailed tests. Application of one-tailed tests, however, are problematic when the results yield a change in the unanticipated direction. Simply switching at that point to the two-tailed test inflates the Type 1 error rate. The authors demonstrate that a better alternative is to use a directed test, in which an asymmetrical pair of rejection regions are defined, the larger of which is applied to the expected direction of change. This means that stronger evidence is needed to reject the null hypothesis when the data differ in the unanticipated direction, but the power (or sensitivity) to detecting change in the anticipated direction is not significantly compromised. The authors provide examples and calculations for a standard t-test, a chi^2 analysis, and a multiway ANOVA.

Type I and Type II errors, statistical interpretation, confidence intervals, statistics overview, power, precision, detecting change, analysis.

1041. Richey, J. S.; Horner, R. R.; Mar, B. W. 1985. **The Delphi technique in environmental assessment. II. Consensus on critical issues in environmental monitoring program design**. Journal of Environmental Management. 21: 147-159.

The Delphi Technique attempts to consolidate information by using the consensus of a panel of experts in an iterative process of response and clarification. In this paper, the summary of the expert opinion on monitoring is presented. Subjects covered are 1) the attributes of hypotheses used to design monitoring programs; 2) criteria for hypothesis selection; 3) identification of sensitive ecosystem components; and 4) selection of measurement parameters. The authors also used the Delphi technique to determine estimates of variability in terms of the percentage of a sample mean for common ecological life forms. For each life form, the sampling error and the natural variability over time were estimated by the mean response values of all participants.

interdisciplinary design, objectives, ecological models, predicting change, biological significance, indicators, natural variability.

1042. Ridsill-Smith, T. J. 1987. **Measuring and monitoring dynamics of remnants**. In: Saunders, D. A.; Arnold, G. W.; Burbidge, A. A.; Hopkins, A. J. M., eds. Nature conservation: the role of remnants of native vegetation. Chipping Norton, Australia: Surrey Beatty and Sons. 373 p.

special sites, natural areas, baseline monitoring, monitoring examples, community-level, community change.

1043. Ringold, P. L.; Alegria, J.; Czaplewski, R. L.; Mulder, B. S.; Tolle, T.; Burnett, K. 1996. **Adaptive monitoring design for ecosystem management**. Ecological Applications. 6(3): 745-747.

The authors describe their experience developing a monitoring plan for the Northwest Forest Plan. Technical and institutional obstacles to the development of a monitoring design include qualitative objectives, inconsistent methods, lack of information on spatial and temporal characteristics of environmental features, and limited agency direction on priorities. Because of these, the authors recommend that monitoring be adaptive, undergoing incremental refinements.

adaptive management, monitoring examples, landscape-level, ecosystem management.

1044. Ripley, T. H.; Johnson, F. M.; Thomas, W. P. 1960. **A useful device for sampling understory woody vegetation**. Journal of Range Management. 13: 262-263.

In sampling cover of browse species along permanent line-intercept transects, it is important to accurately locate the line in the vertical plane both above and below the tape line. The author suggests use of a pole with a sharpened tip at the lower end and a ring bubble similar to that used to level a plane table alidade. The pole ensures rapid plumbed measurements along the tape.

coniferous forest, deciduous forest, canopy cover, cover, line intercept, point intercept, tools, field techniques.

1045. Ripple, W. J. 1994. **Determining coniferous forest cover and forest fragmentation with NOAA-9 advanced very high resolution radiometer data**. Photogrammetric Engineering and Remote Sensing. 60: 533-540.

landscape-level, landscape change, forest, coniferous forest, canopy cover, fragmentation, AVHRR, remote sensing.

1046. Risser, P. G. 1991. **Long-term ecological research: an international perspective**. Scientific Committee on Problems of the Environment (SCOPE) 47. New York, NY: John Wiley and Sons. 294 p.

This book resulted from a study funded by the National Science Foundation to analyze long-term ecological research

in an international context. Two workshops were held in 1988 and 1989 to meet the following objectives: 1) provide a forum for describing and analyzing selected existing long-term ecological research sites and networks from various countries; 2) further refine the rationale for long-term ecological research and identify important existing and emerging scientific questions, and 3) begin to formulate a plan for international communication and coordination among long-term ecological research sites. The results of these workshops and the overall project are presented in the 12 chapters in this book, which describe long-term studies from several countries. Also discussed are topics such as administrative structure, role of long-term research sites, conceptual design, field measurement techniques, and modelling.

long-term ecological monitoring, monitoring examples, global change monitoring, ecological processes, baseline monitoring, field techniques, design.

1047. Risser, P. G. 1995. **The status of the science examining ecotones**. BioScience. 45(5): 318-325.

This paper reviews the status of our knowledge and experience in studying the role of ecotones. Over the past several decades, ecosystem research has led to a recognition and definition of the role of ecotones within the overall landscape. The concept of ecotones has evolved to acknowledge that "ecotones are dynamic components of an active landscape, frequently playing significant roles in supporting high levels of biological diversity as well as primary and secondary productivity; modulating flows of water, nutrients, and materials across the landscape; providing important components of wildlife habitat; and acting as sensitive indicators of global change." Ecotones may occur over a variety of spatial scales. The author draws on existing literature to discuss ecotones from several perspectives, including: biological diversity, flow of materials, wildlife habitat, and global change. Due to the important role of ecotones within a larger ecosystem perspective, this paper provides a valuable review for scientists and managers interested in monitoring vegetation and ecosystem changes. Ecotones may provide the best places to monitor certain aspects of ecosystem and vegetation change.

ecotones, environmental monitoring programs, landscape-level, pattern, predicting change.

1048. Risser, P. G.; Melillo, J. M.; Gosz, J. R. 1991. **Current status and future of long-term ecological research**. In Risser P. G., ed. Long-term ecological research: an international perspective. Scientific Committee on Problems of the Environment (SCOPE) 47. New York, NY: John Wiley and Sons: 275-285.

In this chapter, the authors review and discuss examples of long-term studies, addressing environmental quality, soil processes, fluvial systems, and species responses. All of the examples demonstrate the value and contributions of long-term research. The authors also discuss goals of international and regional networks of long-term research sites, including the need to: 1) identify common patterns of change; 2) develop regional and global syntheses of change and a mechanistic understanding of these changes; 3) partition the variance between global and site-specific processes; and 4) develop approaches to scaling up (and down) from local to regional to global spatial scales.

long-term ecological monitoring, monitoring examples, integrated monitoring, ecological processes, landscape-level, scale.

1049. Risser, P. G.; Zedler, P. H. 1968. **An evaluation of the grasslands quarter method**. Ecology. 49: 1006-1009.

The poin-center quarter method (PCQ) was tested on 6 stands of various Midwestern prairie communities by comparing measures from 50 points and 50 quadrats (10x10cm). Most species were significantly aggregated, but a few were regularly distributed. The PCQ method dramatically underestimated density for the strongly aggregated species, and overestimated density for those that were more regularly distributed. The ratio of estimated densities of the 2 methods for the same species was fairly consistent among the 6 stands.

field techniques, plotless methods, point-center methods, density, grassland, technique comparison.

1050. Ritchie, J. C. 1995. **Current trends in studies of long-term plant community dynamics.** New Phytologist. 130: 469-494.

natural variability, predicting change, community-level, community change, objectives.

1051. Ritchie, J. C.; Everitt, J. H.; Escobar, D. E.; Jackson, T. J.; Davis, M. R. 1992. **Airborne laser measurements of rangeland canopy cover and distribution**. Journal of Range Management. 45: 189-193.

A laser profiler mounted on a small airplane was used to measure the distance between the plane and the landscape surface. The pulse speed allowed for measurements every 1.5cm, and was vertically accurate to within 5cm. Canopy cover measured by laser was compared to that measured by line intercept along approximately the same line. The regression relationship between the two measurement approaches demonstrated close correlation ($r^2 = 0.89$ to 0.98).

field techniques, cover, rangeland, shrub grassland, shrubland, canopy cover, line intercept, remote sensing.

1052. Rittenhouse, L. R.; Sneva, F. 1977. **A technique for estimating big sagebrush production**. Journal of Range Management. 30: 68-70.

field techniques, shrub, production.

1053. Robel, R. J.; Briggs, J. N.; Dayton, A. D.; Hulbert, L. C. 1970. **Relationship between visual obstruction measurements and weight of grassland vegetation**. Journal of Range Management. 23: 295.

field techniques, cover, production, grassland, shrubland.

1054. Roberts, M. R.; Richardson, C. J. 1985. **Forty-one years of population change and community succession in aspen forests on four soil types, northern lower Michigan, USA.** Canadian Journal of Botany. 63: 1641-1651.

All individual tree and shrub stems >1m tall were mapped and diameter measured for those >1.27cm DBH in 4 permanent 0.1 acre plots in 1938, and then at approximately 6-year intervals until 1979. In addition, all woody seedlings were tallied by species for the entire plot. Stands were approximately 20 years old at the time of plot establishment. These data allowed the tracking of mortality, recruitment, and successional changes in composition. Five generalized population patterns were identified: early dominance, delayed dominance, persistence, progressive recruitment, and late recruitment. This paper provides good examples of the kinds of data summarization and interpretation that can be drawn from permanent plot data and measures of growth, mortality, and recruitment of individual trees.

monitoring examples, ecological processes, succession, deciduous forest, long-term ecological monitoring, field techniques, DBH, permanent plots, tree, demographic techniques, seedling.

1055. Roberts, T. H.; O'Neil, J. 1983. **Habitat evaluation methods -- examples and guidelines for selection**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 266-269.

Twenty-eight Habitat Evaluation Methods (HEMs) are classified into one of three categories. Type I uses aerial imagery to identify and classify the presence, quality, and interspersion of perennial cover associations. These methods usually require little or no field sampling. Type II methods evaluate habitat quality for individual species. Approaches in this category range from qualitative to extensive and quantitative. Type III methods assess the quality of the habitat generally or for a suite of species. The application of these HEMs include determining baseline values, developing mitigation or management strategies, and monitoring habitat change.

landscape-level, habitat management, indicators, vegetation mapping, aerial photography, inventory, remote sensing, cover.

1056. Robinove, C. J. 1981. **Efficient arid land monitoring using Landsat images**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 256-259.

pattern, ecosystem management, inventory, large-scale monitoring, Landsat, MSS, remote sensing, rangeland, landscape-level, monitoring examples.

1057. Rock, B. N.; Defeo, N. J.; Vogelmann, J. E. 1987. **Vegetation survey pilot study: detection and quantification of forest decline damage using remote sensing techniques.** D-4669. Pasadena, CA: U.S. Department of Agriculture, Forest Service, Jet Propulsion Laboratory.

Landscape-level, ecosystem management, forest, pattern, landscape change, remote sensing.

1058. Rock, B. N.; Vogelmann, J. E.; Williams, D. L.; Vogelmann, A. F.; Hoshizaki, T. 1986. **Remote detection of forest damage**. BioScience. 36: 439-445.

remote sensing, forest, tree.

1059. Roesch, F. A. 1993. **Adaptive cluster sampling for forest inventories**. Forest Science. 39: 655-669.

In adaptive cluster sampling, a sample is taken and then additional sampling units are selected near those that display the rare condition of interest. For example, in forest sampling initial selection of trees is by standard methods. If an individual tree displays a rare condition, additional trees within a fixed radius of the sample tree are examined for that condition. This is repeated for every tree displaying the condition until no new trees are found with the condition. A key design factor is choosing the radius of the adaptive search area such that additional sampling units are encountered, but search time of the area does not become onerous. Formulas for calculation of mean condition state (in the example presented, the percent defoliation by gypsy moths) per tree and the variance of that estimate are given. This design provides dramatic efficiencies over simple random sampling when either the species or the condition is rare, but spatially distributed in clusters. Only the presence of the rare condition triggers the additional cost of measuring additional sampling units.

coniferous forest, deciduous forest, cluster sampling, sampling design, rare species, design, tree, sample size.

1060. Roesch, F. A. 1994. **Incorporating estimates of rare clustered events into forest inventories**. Journal of Forestry. 92: 31-34.

design, cluster sampling, sampling design.

1061. Rogers, G. F. 1982. **Then and now, a photographic history of vegetation change in the central Great Basin Desert**. Salt Lake City, UT: University of Utah Press. 152 p.

This book compares approximately 50 photographs taken in the late 1800s and early 1900s with duplicated frames taken in the 1970s and 1980s. The changes documented in the photographs are fascinating even for those who do not work with Great Basin vegetation. The book provides methodological suggestions for this type of study, including a field data form to document repeat photographs. Suggested sources of old photographs include university and private collections. The largest collection of historical photographs is archived at the U.S. Geological Survey Photo Library in Denver, CO. The Cartographic Archives Division of the National Archives maintains the pre-World War II collection

of aerial photographs, including sets of large-scale photographs that provide coverage of about 85% of the contiguous U.S.

general examples, field techniques, photopoints, long-term ecological monitoring, aerial photography.

1062. Rogers, G. F.; Malde, H. E.; Turner, R. M. 1986. **Bibliography of repeat photography for evaluating landscape change**. Salt Lake City, UT: University of Utah Press. 179 p.

The introduction to this book provides an overview of the use of historical photographs combined with retaken photographs for assessing change in vegetation and landscapes.

field techniques, landscape-level, community-level, photopoints, landscape change, community change.

1063. Rogers, G. F.; Turner, R. M.; Malde, H. E. 1983. **Using matched photographs to monitor resource change.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 90-91.

Repeat photographs can provide valuable information on changes from historic conditions. Repeat photographs should be taken from the same point toward the same point. If location and direction are correct, use of different size lenses will provide more or less of the original frame, but the geometric properties will remain the same and photos can be compared. Shadows should be duplicated by retaking photos at the same time of day as the original. Larger format cameras (with 4x5in negatives or larger) are preferable because of their greater clarity.

field techniques, landscape-level, community-level, photopoints, landscape change, community change.

1064. Rogers, P. 1996. **Disturbance ecology and forest management: a review of the literature**. Gen. Tech. Rep. INT-336. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 16 p.

disturbance, objectives, natural variability, ecological models, forest, ecosystem management, ecological processes, landscape planning, landscape-level.

1065. Root, T. L.; Schnieder, S. H. 1993. **Can large-scale climatic models be linked with multiscale ecological studies?** Conservation Biology. 7: 256-270.

monitoring examples, integrated monitoring, global change monitoring, scale, ecological monitoring programs.

1066. Roozen, A. J. M.; Westhoff, V. 1985. **A study on long-term salt marsh succession using permanent plots**. Vegetatio. 61: 23-32.

wetland, permanent plots, long-term ecological monitoring, monitoring examples, community-level, community change, succession.

1067. Rose, K. A.; Smith, E. P. 1992. **Experimental design: the neglected aspect of environmental monitoring**. Environmental Management. 16: 691-700.

The authors express concern that in many studies, monitoring data are collected without explicit statement of the hypotheses and with little attention to experimental design. This results in a mismatch of data and data uses caused by inappropriate design, changing hypotheses, and use of data collected for one question to answer another. The practical result of these issues is demonstrated in a review of two studies on the trend of dissolved oxygen in Chesapeake Bay. Neither data set was collected for the purpose of measuring dissolved oxygen. The conclusions drawn from the two data sets are contradictory, thus the data cannot serve as a basis for decision-making. These studies are "data rich but information poor." The authors propose that hypotheses be explicitly formed, in the tradition of experimental design, and that initial data be collected on a pilot basis. Designs should be hierarchical and nested, incorporating several spatial and temporal scales in order to assess the natural range of variability that must be addressed by the monitoring.

design, experimental design, sampling design, objectives, monitoring and management.

1068. Rosema, A.; Verhoef, W.; Noorbergen, H.; Borgesius, J. J. 1992. **A new forest light interaction model in support of forest monitoring**. Remote Sensing of The Environment. 42: 23-41.

Landsat Thematic Mapper data has high potential for cost-efficient use in monitoring forest resources on widely-distributed small forest tracts. The authors found in a review of the literature that Landsat TM provides mixed results. They evaluated the two major models of canopy light interaction: the Suits Model which considers the canopy to be one or more homogeneous transparent canopy layer(s) and the Strahler-Li model which describes the forest as a composite of opaque geometric shapes. The first considers the influence of understory layers, but does not model well the effects of clumpiness, open spots, and shadows. The second model recognizes shadows, but not crown transparency. The alternate model developed here describes the canopy in terms of probabilities of viewing the ground or the canopy. Crown ground coverage, crown leaf area index, and crown yellowness were evaluated with TM Bands 3, 4, and 5. Comparisons with available ground data suggest fair correlation, but conclusions were limited by the poor quality of the ground data.

remote sensing, coniferous forest, deciduous forest, Landsat.

1069. Rosen, R. 1978. **Fundamentals of measurement and representation of natural systems**. New York, NY: Elsvier Press. 221 p.

vegetation sampling overview, field techniques.

1070. Roshier, D.; Lee, S.; Boreland, F. 1997. **A digital technique for recording of plant population data in permanent plots**. Journal of Range Management. 50(1): 106-109.

A mobile truck-mounted digitizing system is described. This system has been used successfully for demographic monitoring of plant population dynamics in 120 large (4x3m) permanent plots in western New South Wales.

demographic techniques, permanent plots, charting, rangeland.

1071. Rotenberry, J. T.; Wiens, J. A. 1985. **Statistical power analysis and community-wide patterns**. American Naturalist. 125: 164-168.

The authors point out that one of the problems with using power analysis to assess the strength with which a null hypothesis can be "accepted" is that there is no conventional method for estimating a priori the magnitude of the expected effect size. Power curves are extremely steep at low values of effect size, thus the results of power analysis are extremely sensitive to the choice of effect size, a choice which is subjective unless some information is available on the size of the effect that can be expected. They offer an alternate approach used after one has failed to reject a null hypothesis in which the maximum detectable effect size that can be detected with the Type I and II error rates equal is calculated (the comparative detectable effect size, CDES). If CDES seems biologically insignificant, the null hypothesis is affirmed.

analysis, design, statistical interpretation, biological significance, power, precision, Type I and Type II errors.

1072. Rothery, P. 1974. **The number of pins in a point quadrat frame**. Journal of Applied Ecology. 11: 745-754.

field techniques, point intercept, cover, point frames.

1073. Rowell, J. G.; Walters, D. E. 1976. **Analyzing data with repeated observations on each experimental unit**. Journal of Agricultural Science. 87: 423-432.

analysis, repeated measures analysis.

1074. Rugh, J. C.; Peterson, D. L. 1992. **Inventory and monitoring in the national parks: forging a plan**. Park Science. 12(4): 1-4.

monitoring overviews, monitoring examples, national parks, special sites.

1075. Runkle, J. R. 1985. **Comparison of methods for determining fraction of land area in treefall gaps**. Forest Science. 31: 15-19.

disturbance, landscape-level, coniferous forest, deciduous forest, forest, design, sampling design.

1076. Ruyle, G. B., ed. 1991. **Some methods for monitoring rangelands and other natural area vegetation**. Ext. Rep. 9043. Tucson, AZ: University of Arizona.

vegetation sampling overview, monitoring overviews, field techniques, natural areas, special sites, rangeland.

1077. Rykiel, E. J. 1985. **Towards a definition of ecological disturbance**. Australian Journal of Ecology. 10: 361-365.

landscape-level, disturbance.

1078. Sample, V. A., ed. 1994. **Remote sensing and GIS in ecosystem management**. Washington, DC: Island Press. 368 p.

This book explores the use of remote sensing combined with GIS for the landscape-level analysis needed for ecosystem management in forested ecosystems. Case studies are provided for each major forested region in the U.S.

landscape-level, monitoring examples, remote sensing, Landsat, ecosystem management, GIS, pattern, landscape change, scale, forest, large-scale monitoring.

1079. Samuel, M. J.; Hart, R. H. 1994. **Sixty-one years of secondary succession on rangelands of the Wyoming high plains**. Journal of Range Management. 47: 184-191.

general examples, succession, frequency, production, rangeland, grassland, disturbance, community-level, community change.

1080. Sandland, R. L.; Alexander, J. C.; Haydock, K. P. 1982. **A statistical assessment of the dry-weight-rank method of pasture sampling**. Grass and Forage Science. 37: 268-272.

field techniques, production, dry-weight-rank, grassland.

1081. Saunders, D.; Arnold, G.; Burbridge, A.; Hopkins, A., eds. 1993. **The role of remnants of native vegetation**. Minneapolis, MN: University of Minnesota Press. 410 p.

special sites, natural areas, protected areas, baseline monitoring, general examples, objectives.

1082. Saunders, D. A.; Hobbs, R. J.; Margules, C. R. 1991. **Biological consequences of ecosystem fragmentation: a review**. Conservation Biology. 5: 18-32.

In this review, the authors consider the changes in biota that occur from the physical effects of fragmentation on fluxes of radiation, wind, water, and nutrients across the landscape. They also review the effects of isolation, and the moderating aspects of time, distance from other fragments, connections between fragments, and remnant size, shape, and landscape position. Emphasis in the conservation literature has been on the design of nature reserves--choosing the ideal set from an area about to be fragmented. In the real world, systems are already fragmented, and the reserve system must be created out of the fragments left behind. Using the information in the review, the authors suggest management considerations for remnant natural areas: 1) determine priorities for a minimum subset of existing remnants needed to capture the diversity of an area; 2) manage external influences as part of the entire system in order to maintain diversity; 3) establish management priorities so that problems

most likely to disrupt ecosystem processes are addressed first; and 4) recognize that remnant areas will require continuous management in order to be maintained in their present state, since many of the ecosystem functions that shaped those areas no longer occur.

special sites, landscape-level, natural areas, biodiversity, corridors, ecological processes, ecosystem, disturbance, ecosystem management, fragmentation, pattern, landscape change, pattern, scale.

1083. Sayn-Wittgenstein, L. 1961. **Recognition of tree species on air photographs by crown characteristics**. Photogrammetric Engineering and Remote Sensing. 27: 792-809.

tree, forest, aerial photography, remote sensing, crown diameter, community-level, community composition.

1084. Schaeffer, D. J.; Herricks, E. E.; Kerster, H. W. 1988. **Ecosystem health: I. Measuring ecosystem health**. Environmental Management. 12(4): 445-455.

monitoring overviews, objectives, environmental monitoring programs, general examples, landscape-level, ecosystem, ecological processes, ecosystem management.

1085. Schamberger, M. 1988. **Monitoring wildlife habitat: a critique of approaches**. Statistical Journal of The United Nations ECE. 5: 303-313.

The author describes habitat monitoring as an effort to monitor the physical conditions that provide life support for the species of interest. Key design isses are selecting the parameter to be monitored and determining the methodology. General monitoring of vegetative type (wetland, shrub, etc.) with aerial photography may be adequate when the quality of habitat is thought unimportant. When quality is important, the factors monitored could be those identified important in habitat models. Landsat data such as the percent canopy cover of trees or annual snow cover is an example of habitat monitoring using remote sensing.

monitoring overviews, habitat management, habitat mapping, remote sensing, Landsat, landscape-level, community-level, vegetation mapping, objectives.

1086. Scheiner, S. M.; Gurevitch, J., eds. 1993. **Design and analysis of ecological experiments**. New York, NY: Chapman and Hall. 445 p.

This book is designed to introduce ecologists to some of the lesser known, but useful analysis techniques. Most of the chapters are built around a type of ecological problem or experiment. Techniques include ANOVA and ANCOVA (field competition experiments), repeated measures analysis (growth), time-series intervention analysis (unreplicated large-scale experiments), multiple regression (herbivory), path analysis (pollination), and the bootstrap and jackknife. Formulas and mathematics are minimal, with most authors preferring conceptual explanations, examples, and computer-generated results.

analysis, design, bootstrap, jackknife, experimental design, sampling design, ANOVA, MANOVA, repeated measures analysis, statistics overview, time series, covariance, large-scale monitoring, randomization tests.

1087. Schindler, D. W. 1987. **Detecting ecosystem responses to anthropogenic stress**. Canadian Journal of Fisheries and Aquatic Sciences. 44: 6-25.

monitoring examples, detecting change, design, long-term ecological monitoring, large-scale monitoring, aquatic.

1088. Schindler, D. W. 1990. **Experimental perturbations of whole lakes as tests of hypotheses concerning ecosystem structure and function**. Oikos. 57: 25-41.

design, aquatic, landscape-level, ecological processes, ecosystem management, monitoring examples, large-scale monitoring, disturbance.

1089. Schlesinger, R. C.; Funk, D. T.; Roth, P. L.; Myers, C. C. 1994. **Assessing changes in biological diversity over time**. Natural Areas Journal. 14: 235-240.

The authors report changes in vascular plant diversity over a 37-year period in the Pioneer Mothers' Memorial Forest Research Natural Area in southern Indiana. Data from permanent plots installed in 1978 (and re-sampled in 1989) and data from stand level sampling between 1941 and 1972 were utilized to calculate three indices; species richness, heterogeneity (Shannon-Weiner diversity index), and equitability (Pielou's evenness index). Shannon-Weiner index values were calculated for both abundance and basal area. Subplots were selected from the 153 permanent 0.1-ha circular plots for comparision to earlier stand level data. Permanent plot data were analyzed with a jackknifing technique. Analysis of variance was computed for comparisons between permanent plot data and data from earlier studies. The authors state that permanent plot data provide the best way to assess vegetation changes over time, but they also offer a technique for utilizing other data where permanent plot data are lacking.

natural areas, long-term ecological monitoring, permanent plots, diversity indices, randomization tests, jackknife, ANOVA, community change, community composition, field techniques, analysis, community-level, monitoring examples, special sites, forest, deciduous forest.

1090. Schmelz, D. 1969. **Testing the quarter method against full tallies in old growth forests**. Proceedings of the Indiana Academy of Sciences. 79: 138.

Full counts were compared with point-quarter distance measurements (sampling intensity of 2 points per acre). The point-quarter method consistently overestimated stand basal area, with an average overestimation of 39% and a range of 1% to 99%. Density was overestimated by as much as 60%. The point-quarter method detected only 43% to 73% of the species found in the stand.

field techniques, forest, tree, distance methods, point-center methods, density, plotless methods, basal area.

1091. Schmid-Haas, P. 1981. **Monitoring change with combined sampling on aerial photographs and on the ground**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 383-388.

Permanent plots are recommended for monitoring, but the presence of visual markers such as posts may result in special treatment of the plot area, thus compromising their use for representing overall stand dynamics. In Switzerland, thousands of permanent plots lacking obvious markers have been relocated, often in rough terrain. Only a few have been lost. Each plot center is located with a compass and tape from a landmark. The distance and azimuth to 2 additional points are measured. The polar coordinates of all trees are measured with respect to the plot center. Finally, a metal pipe is buried at plot center. In most cases, the distance and direction from plot trees is adequate to exactly relocate the plot center. Stratification using aerial photographs reduced the number of ground plots by 2 or 3 times. A combination of sampling of some characteristics on aerial photos and others on ground plots has been found most efficient.

tree, forest, monitoring examples, design, inventory, large-scale monitoring, aerial photography, stratified sampling, monumentation, permanent plots.

1092. Schmid-Hass, P. 1983. **Swiss continuous forest inventory: twenty years experience**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 133-140.

Forest stands are stratified using aerial photos into similar types, requiring about a third of the sampling units to estimate type qualities such as volume with the same precision as a non-stratified system. Permanent plots were much more effective for measuring change, requiring only 60 plots to provide the same precision as 375 temporary plots. To avoid permanent sampling units from being treated differently from surrounding areas, plots are marked with a completely sunken center post. To aid relocating plot centers, distance and azimuth from plot center to all trees on the plot are measured; in practice this generally allows for relocation within 10cm. Plot methodology requires measurement of all trees 50cm or more DBH within a 300 to 600m² circular plot, and for smaller trees within a centered plot 50 to 100m². For each tree, height, diameter at breast height, and diameter at 7m from the ground are measured. Finnish calipers have proven superior to optical instruments for measuring the diameter at the 7m height.

design, tools, monitoring examples, large-scale monitoring, coniferous forest, deciduous forest, DBH, aerial photography, permanent plots, sampling design, two-stage sampling, monumentation, tree, heights.

1093. Schmoldt, D. L.; Peterson, D. L.; Silsbee, D. G. 1994. **Developing inventory and monitoring programs based on multiple objectives**. Environmental Management. 18: 707-727.

When many objectives have been developed, some method of allocating limited monitoring resources becomes necessary so that the most critical objectives are best monitored. The authors describe a method of ranking monitoring projects using the Analytic Hierarchy Process. In the example given, 8 general objectives are each subdivided into more specific objectives. For example, the objective "better understanding of resources" is further refined to 1) maintain familiarity with resources; 2) provide background information; and 3) provide understanding of ecosystem function. In working through this example, the paper also supplies a number of considerations or criteria for monitoring. Ranking values are assigned to the potential projects. These will vary depending on which of the general objectives (or combination of them) is most important.

monitoring overviews, monitoring and management, objectives, interdisciplinary design.

1094. Schmoldt, D. L.; Peterson, D. L.; Silsbee, D. G. 1991. **Strategic inventory and monitoring programs: prioritizing projects and allocating expenditures**. Draft Rep. Seattle, WA: U.S. Department of Interior, National Park Service, Cooperative Park Studies Unit. 42 p.

monitoring overviews, objectives.

1095. Schmutz, E. M. 1971. **Estimation of range use with grazed-class photo guides**. Bull. A-73. Tuscon, AZ: University of Arizona Cooperative Extension Service and Agricultural Experiment Station. 16 p.

field techniques, utilization, rangeland, herbaceous species, grassland.

1096. Schoonmaker, P.; Mckee, A. 1988. **Species composition and diversity during secondary succession of coniferous forests in the western Cascade Mountains of Oregon**. Forest Science. 34(4): 960-979.

succession, forest, species diversity, community composition, community change, community-level.

1097. Schranck, B. W. 1984. **Natural area management of Montana national wildlife refuges**. In: Johnson, J. L.; Franklin, J. F.; Krebill, R. G., coordinators. Research natural areas: baseline monitoring and management; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 75-76.

objectives, special sites, natural areas, monitoring and management.

1098. Schreuder, H. T.; Alegria, J. 1995. **Stratification and plot selection rules: misuses and consequences**. Res. Note RM-RN-536. Ft. Collins, CO: U.S. Department of

Agriculture, Forest Service, Rocky Mountain Experiment Station. 4 p.

sampling design, design, plot selection, random sampling, stratified sampling.

1099. Schreuder, H. T.; Brink, G. E. 1983. **The jackknife--a useful statistical tool**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 532-535.

The basic concept of the jackknife is described in which the mean and standard error of a data set are estimated by repeatedly deleting one or more units from the data set, and resampling. Some basic recommendations are provided: 1) delete the same proportion of sample units for each resampling period; 2) if small samples to be deleted are subsets of a larger one, those same small deleted samples should be part of the group that is targeted for deletion from the larger set (they should be linked); 3) using a smaller sample (subset) is more effectve than larger ones, especially in multiple-sample designs; and 4) there may be many combinations of samples, once deletions begin, thus the number of these to use must be determined by computer capability and time. Three examples are given, one for each the simple random design, simple random sampling with regression estimation, and a sampling with partial replacement design.

analysis, design, precision, sampling design, jackknife, randomization tests.

1100. Schreuder, H. T.; Czaplewski, R. L. 1993. **Long-term strategy for the statistical design of a forest health monitoring system**. Environmental Monitoring and Assessment. 27: 81-94.

monitoring overviews, forest, tree, ecosystem management, landscape-level, disturbance, design, sampling design, large-scale monitoring, monitoring examples.

1101. Schreuder, H. T.; Gregoire, T. G.; Wood, G. B. 1993. **Sampling methods for multiresource forest inventory**. New York, NY: John Wiley and Sons. 464 p.

This is a technical book on all aspects of inventory sampling of forest timber resources. The book is primarily directed at commercial resources such as density and volume, but a short chapter contains information on sampling fish and wildlife populations, "lower" vegetation, regeneration, and rare populations. The bulk of the book deals with sampling design and the concepts found in these chapters are useful for any study that requires sampling: determination of sample size; designs with and without a sampling frame; jackknife and bootstrap estimation of variance; and specific techniques such as fixed plots, variable plots, Poisson sampling, critical height sampling, importance sampling, and ranked set sampling. Some additional subjects covered are remote sensing, missing data analysis, and Bayesian and likelihood estimation. The book is written for biometricians and graduate level students interested in forest inventory.

analysis, statistics overview, forest, inventory, sampling design, precision, randomization tests, remote sensing, cluster sampling, sample size.

1102. Schroeder, R. L.; Keller, M. E. 1990. **Setting objectives-- a prerequisite to ecosystem management**. In: Mitchell, R. S., ed. Ecosystem management: rare species and significant habitats. NY State Museum Bull. 471. Albany, NY: New York State Museum: 1-4.

The process of identifying desired end conditions--setting objectives--is critical for effective management, especially when larger and more complex systems are considered. The entire management effort is affected by the choice and definition of objectives, and since they are stated in a measurable format, the type of monitoring is similarly directed. Setting objectives requires: 1) the identification of the boundaries and priorities; 2) the determination of the significant aspects of the ecosystem; 3) the identification of indicators or measureable aspects of ecosystems that are barometers of the overall goals; and 4) an awareness of the relationship between national, regional, and local efforts and a consideration of cumulative and landscape level concerns. Objectives should be concise, clear, and measureable. Ambiguous terms such as "diversity," "habitat suitability," and "ecological condition" should be replaced by specific, measureable ecosystem attributes. The author acknowledges that setting objectives can be difficult because of imperfect knowledge, inadequate use of data (gap between theoretical and applied ecology), conflicting goals, and the lack of institutional memory.

monitoring overviews, objectives, ecosystem management, indicators, agency guidance and policy, monitoring and management, ecological models, predicting change.

1103. Schroeter, S. C.; Dixon, J. D.; Kastendiek, J.; Smith, R. O. 1993. **Detecting the ecological effects of environmental impacts: a case study of kelp forest invertebrates**. Ecological Applications. 3: 331-350.

design, aquatic, detecting change, BACI, sampling design, experimental design, power.

1104. Schuck, A.; Parviainen J.; Bucking W. 1994. **A review of approaches to forestry research on structure, succession and biodiversity of undisturbed and semi-natural forests and woodlands in Europe**. Working Pap. 3. Joensuu, Finland: European Forest Institute. 62 p.

Presented is a literature review on the history of forest reserves, research efforts, and definitions of forest ecosystems and protected areas in Europe. This review was conducted as the first step in development of a new study entitled "Instruments for depicting forest biodiversity using a network of permanent sample plots in undisturbed forests in order to improve silvicultural practices in Europe." The authors discuss the many types of forest reserves throughout Europe, and provide a good overview of research and

management of these areas. Also reviewed are some of the many permanent plot studies established to study stand structure and change over time. This paper provides a good perspective on the value of forest reserves and protected areas to the European scientific community.

disturbance, reference areas, ecological monitoring programs, permanent plots, national parks, protected areas, special sites, monitoring examples, field techniques, tree, forest, woodland.

1105. Schultz, B. B. 1989. **In support of the use of significance tests and of unplanned pairwise multiple comparisons**. Environmental Entomology. 18: 901-907.

analysis, multiple comparisons.

1106. Schultz, B. W.; Oster, W. K. 1995. **Species and community response to above normal precipitation following prolonged drought at Yucca Mountain, Nevada**. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 236-242.

The response of Mohave Desert vegetation to increased moisture after a prolonged drought was monitored over 3 years. Canopy cover was measured in 200x200m study plots (12 plots in each of 4 vegetation types), using point intercept. Points were measured with an ocular scope at 1m intervals on 8 to 10 transects (50m). Counts of all perennial plants were also made in 8 to 10 quadrats (2x50m) at each site. Density data were collected in contiguous 2x2m subplots, an approach which had been found to reduce the number of missed and doubly counted individuals. Average cover over all sites increased from 8.6% to 12.7%. The percent change in cover (cover at the end of the monitoring period divided by that at the beginning) was 200% to 300% for some species, and for over half of the species it was over 30%. Density also changed but not as dramatically. Most percent change values were under 5%. The combined density and cover monitoring method allowed for stronger biological interpretation about species response to increased moisture than either measure would have alone.

biological significance, objectives, community composition, community structure, community change, cover, predicting change, desert, density, canopy cover, point intercept, monitoring examples, ecological monitoring programs, field techniques, community-level.

1107. Schumacher, F. X.; Chapman, R. A. 1948. **Sampling methods in forestry and range management**. Bull. 7. Durham, NC: Duke University School of Forestry. 222 p.

field techniques, rangeland, forest.

1108. Schuster, J. L. 1965. **Estimating browse from twig and stem measurements**. Journal of Range Management. 18: 220-223.

shrub, shrubland, utilization, field techniques, production.

1109. Schwegman, J. 1986. **Two types of plots for monitoring individual herbaceous plants over time**. Natural Areas Journal. 6(1): 64-66.

The "T Square" quadrat is constructed of two meter rulers that intersect and connect in the center. One of the two has a hole drilled near each end that fits over PVC pipe or metal stakes that permanently mark the plot in the field. Locations of individual plants are noted using an XY coordinate system created by the crossing meter rulers. The second method is used for circular quadrats up to 3m in diameter. The plotter is constructed with a protractor mounted on a frame that fits over 2 permanent field marking stakes. A tape that swivels from the center is used to note azimuth on the protractor and distance from center. Complete directions and diagrams for both tools are given.

field techniques, permanent plots, demographic techniques, rare species, charting, tools, herbaceous species.

1110. Scott, C. T.; Ek, A. R.; Zeisler, T. R. 1983. **Optimal spacing of plots comprising clusters in extensive forest inventories**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 707-710.

A cluster design is often employed in forest sampling to reduce travel costs between sampling units. A system of clusters of plots, however, is less efficient than completely randomly located plots for estimating the mean, thus creating a trade-off between reduced travel time and reduced precision. Clusters comprised of plots separated by distances ranging from 40 to 1600m were compared for costs (travel time) and precision to determine the optimal spacing. Optimal configurations varied for the different attributes, but no optimal distance was less than 220m. Optimal plot numbers ranged from 4 to 7 and distances from 220 to 1250m. Relatively small changes in location costs (finding the cluster and travel to and from vehicle to cluster), travel time between plots, and plot measurement time could result in optimal distance changes of up to 88%. In order of importance these guidelines were suggested: 1) observe >2 plots per cluster; 2) sample as many plots/working day as travel and location time allow; 3) separate plots as far apart as time allows; and 4) place plots in the most field efficient manner possible (configuration had little effect).

design, tree, forest, sampling design, cluster sampling.

1111. Scott, C. T.; Kohl, M. 1994. **Sampling with partial replacement and stratification**. Forest Science. 40: 30-46.

sampling design, design, stratified sampling, tree, forest.

1112. Scott, D. 1989. **Biological monitoring of rivers**. In: Craig, B., ed. Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on protected

natural areas; 1988 May; Dunedin. Wellington: Department of Conservation: 153-160.

Three categories of monitoring are described: 1) surveillance, which involves repetitive measurements at one or more sites to detect changes; 2) compliance, which measures whether the conditions of the permit are being met; and 3) receiving water monitoring, which determines whether the classified or other standards are being met. The management needs, current condition of the water, and proposed uses will affect the choice of the biological indicator, sampling location, frequency of sampling, and sample size. Analysis will also be variable. Composite biotic indices utilizing tolerance information for several species condense complicated information, but may not have widespread applicability. Diversity indices have shown mixed effectiveness as an indicator of impact. The correlation between pollution and diversity is not always linear or direct. Multivariate comparisons using similarity indices have been shown useful in the few studies where they have been applied.

ecological monitoring programs, monitoring examples, aquatic, environmental monitoring programs, similarity measures, diversity indices, analysis, community-level, community change.

1113. Scott, D. 1965. **A height frequency method for sampling tussock and shrub vegetation**. New Zealand Journal of Botany. 3: 253-260.

grassland, herbaceous species, field techniques, frequency, heights, shrub, shrubland, shrub grassland.

1114. Scott, D.; Dick, R. D.; Hunter, G. G. 1988. **Changes in the tussock grasslands in the central Waimakariri River Basin, Canterbury, New Zealand**. New Zealand Journal of Botany. 26: 197-222.

field techniques, monitoring examples, herbaceous species, cover, long-term ecological monitoring, permanent plots, line intercept, grassland.

1115. Sestak, M.; Riebau A. 1992. **Wilderness monitoring research in the Bureau of Land Management**. Defining wilderness quality: the role of standards in wilderness management -- a workshop proceedings; 1990 April 10-11; Fort Collins, CO. Gen. Tech. Rep. GTR-305. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Experiment Station: 88-93.

special sites, wilderness, monitoring examples, agency plans, baseline monitoring.

1116. Shampine, W. J. 1993. **Quality assurance and quality control in monitoring programs**. Environmental Monitoring and Assessment. 26: 143-151.

For monitoring to be successful, mechanisms for ensuring the quality of the data must be included as part of planning. The quality of the data should be known, with a description of the conditions associated with data collection and handling. The data quality should be consistent over the life of the monitoring project so comparisons can be made. A plan for quality assurance that identifies the actions necessary to ensure the data will be satisfactory should be part of the design of monitoring. A system of quality control must also be implemented that describes the day-to-day actions needed to ensure quality.

analysis, data management.

1117. Shanks, R. E. 1954. **Plotless sampling trials in Appalachian forest types**. Ecology. 35: 237-244.

Two plotless techniques, the Bitterlich variable-radius plot and the random pairs method, were compared to traditional plot sampling (1/10 and 1/40 acre plots). There were 40 sampling units for each design, but since the random pairs method only measures 2 trees at each point, the sample size on which basal area was based was about one-fourth that of the next largest number of sample trees (the 1/40 acre plot). The largest number of individual trees was sampled with the variable radius plot. The variable-radius sample also approximated a normal distribution and in the forest stand described in this paper, only required 7 sampling points to provide a standard error of ±10% of the mean (95% confidence). The author concluded that variable-radius plot sampling was advantageous for the estimation of basal area, species composition, and frequency because of its speed (several times faster than traditional plot sampling), the requirement for only a single observer, and its normally distributed sample data. Random pairs sampling was found to underestimate clumped species, produce a skewed sampling distribution on tree number and basal area, and produce only a small sample size for frequency. Neither of the plotless methods efficiently sampled the rare species.

community composition, forest, distance methods, random pairs, plotless methods, variable plots, technique comparison, basal area, density, community-level, field techniques.

1118. Sharik, T. L.; Ross, M. S.; Price, A. H. 1983. **A micro-borer for extracting increment cores from small stems of woody plants**. Forest Science. 29(2): 329-331.

field techniques, tree-ring analysis.

1119. Sharp, L. A. 1954. **Evaluation of the loop procedure of the 3-step method in the salt-desert shrub type in southern Idaho**. Journal of Range Management. 7: 83-88.

Three observers each measured the same clusters of three 100ft transects using a 3/4in diameter loop at 1ft intervals. All plant species occurring within the loop were recorded. The loop was also recorded as a "hit" on bare ground, rock, or litter if more than half of the loop was filled by that class. Each cluster was located in a different vegetation type: shadscale, saltsage, and a crested wheatgrass seeding. Two measurements of each transect were completed 10 weeks apart to assess the changes due to re-establishment of the tapeline. Differences among observers was only significant (5% level) in 3 instances: twice for shrubs and once for bare ground. Although not significant, measurement of litter showed the greatest variability among observers. Dried

annuals and moss were inconsistently interpreted as litter, and observers differed on interpretation of what constituted "half full." Other differences between observers were attributed to the failure to hold the rod at plumb, failure to note small species, especially annuals, and differences in opinion about what constituted a "hit" on vegetation (closed canopy versus occasional lateral branches). Re-established transects on the second reading showed good agreement with the first: over 70% of the loop readings were identical.

desert, rangeland, shrub grassland, shrubland, loop frames, observer variability, ocular estimation, field techniques, cover, frequency.

1120. Sharp, L. A.; Sanders, K.; Rimbey, N. 1990. **Forty years of change in a shadscale stand in Idaho**. Rangelands. 12: 313-328.

This paper represents one of the best rangeland examples of changes recorded by duplicated photopoints over time.

field techniques, shrub grassland, rangeland, photopoints, community-level, detecting change, monitoring examples, long-term ecological monitoring.

1121. Sharrow, S. H.; Tober, D. A. 1979. **A simple, lightweight point frame**. Journal of Range Management. 32: 75-76.

field techniques, cover, point intercept, point frames, tools.

1122. Shaw, D.; Greenleaf, J.; Berg, D. 1993. **Monitoring new forestry**. Environmental Monitoring and Assessment. 26: 187-194.

monitoring and management, landscape-level, ecosystem management, monitoring overviews, monitoring examples.

1123. Shivers, B. D.; Borders, B. E. 1996. **Sampling techniques for forest resource inventory**. New York, NY: John Wiley and Sons. 359 p.

This book covers a wide range of sampling issues and design for forest inventory. The authors make few assumptions about the statistical expertise of the reader, thus the book can function as an introductory reference.

inventory, forest, tree, sampling design, variable plots, design, precision, sample size, stratified sampling, systematic sampling, two-stage sampling.

1124. Shmida, A. 1984. **Whittaker's plant diversity sampling method.** Israel Journal of Botany. 33: 41-46.

This method of sampling vegetation was developed over the course of a decade of field sampling, primarily in semiarid environments. Each plot 20x50m in size. A 50m baseline denotes the mid-axis of the plot. Along this tape, one 10x10m plot is selected based on its representativeness of the community enclosed by the 20x50m plot. Ten contiguous 1m² plots are arranged along one side of the tape, and two 1x5m plots along the other, together defining a strip 2x10m. Species presence is noted within the 1m² blocks and the 1x5m plots. Species not occurring in these but occurring within either the 10x10m plot or the 20x50m plot are also noted. For each species, additional notes on cover (either visual estimates or line-intercept measures along the baseline), growth form, and phenological characters are recorded. The nested base-10 design allows for development of species area curves for comparison of sites, rather than the single index that is calculated from a single-sized plot.

community-level, biodiversity, community composition, community structure, diversity indices, species richness, species lists, species diversity, cover, canopy cover, line intercept, frequency, sampling design, field techniques, design, ocular estimation.

1125. Shoop, M. C.; McIlvain, E. H. 1963. **The micro-unit forage inventory method**. Journal of Range Management. 16: 172-179.

rangeland, herbaceous species, inventory, field techniques, frequency.

1126. Shrader-Frechette, K. S.; McCoy, E. D. 1992. **Statistics, costs and rationality in ecological inference**. Trends In Ecology and Evolution. 7: 96-99.

monitoring and management, analysis, statistical interpretation.

1127. Shugart, H. H.; West, D. C. 1981. **Long-term dynamics of forest ecosystems**. American Scientist. 69: 647-652.

community-level, succession, forest, long-term ecological monitoring, predicting change, natural variability.

1128. Shumway, R. H. 1988. **Applied statistical time series analysis**. Englewood Cliffs, NJ: Prentice-Hall. 379 p.

statistics overview, analysis, time series.

1129. Sikora, P. C. 1983. **Efficient tree height measurement utilizing a hand-held calculator**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 690-692.

A formula is given for each of the 2 common methods for measuring tree heights. This formula can be programmed with most hand-held calculators or field computers for easy field application. The tape method requires measurement of the distance between the observer and the base of the tree and the angle of departure from horizontal of the top of the tree and the base. The height-pole method uses a pole of known height held at the base of the tree, and the angles of departure from horizontal of the observer to top of tree, top of pole, and base of tree.

tools, field techniques, heights, tree.

1130. Silsbee, D. G.; Peterson, D. L. 1991. **Designing and implementing comprehensive long-term inventory and monitoring programs for National Park System lands**. Natural Resources Rep. NPS/NRUW/NRR-91/04.

Washington, DC: U.S. Department of Interior, National Park Service. 13 p.

This paper provides interesting background information and discussion on major issues associated with designing inventory and monitoring programs for national parks and related reserves and covers the following topics: 1) objectives, 2) attribute selection, 3) method development, and 4) institutional frameworks. The authors use characteristics of actual and proposed programs to identify trade-offs and pitfalls inherent in designing successful inventory and monitoring programs.

objectives, national parks, ecological monitoring programs, sampling design, indicators, monitoring examples, inventory, special sites, design, monitoring overviews, long-term ecological monitoring.

1131. Silsbee, D. G.; Peterson, D. L. 1993. **Planning for implementation of long-term resource monitoring programs.** Environmental Monitoring and Assessment. 26: 177-185.

While standard monitoring protocols and measured parameters require less planning time, they are rarely as efficient as specifically designed monitoring. The purposes of monitoring differ, ranging from identification of needed management actions to measuring ecosystem dynamics and trends. In designing specific monitoring projects, specific objectives must be articulated. Specific system attributes measured may be chosen based on their value, sensitivity, ease of measurement, or comparison value. Monitoring sites may be chosen randomly, or because of their significance or representativeness. Methods should be simple and robust to changes in personnel, while not sacrificing data quality or statistical rigor. Prior to implementing the monitoring design over the long term, a pilot period should be used to determine whether an affordable sample size can meet objectives of statistical precision and power. A flow chart describes the planning process for monitoring.

design, monitoring overviews, objectives, pilot study, precision, power, sampling design.

1132. Simberloff, D.; Farr, J. A.; Cox, J.; Mehlman, D. W. 1992. **Movement corridors: conservation bargains or poor investments?** Conservation Biology. 6: 493-504.

Landscape-level management and monitoring objectives often assume corridors are important. The authors suggest, however, that the touted benefits of corridors are largely based on environmental hype rather than actual data. The authors discount the common justifications of corridors: 1) the need for movement areas in the event of global warming; 2) equilibrium theory of island biogeography and demographic stochasticity and the need for new colonists; 3) inbreeding depression and the need for novel genetic material; and 4) the assumed need of some species for movement over large areas. The authors assert these theories are unproven or have been shown erroneous, and there is no evidence that corridors ameliorate these problems even if they exist. While a number of researchers have suggested that corridors may be important (many of these are reviewed and refuted here), there are only a few empirical studies showing that corridors receive use over that occurring across non-corridor areas. Conversely, corridors may actually be disadvantageous, causing a reduction in genetic drift and site-specific evolution, an increase in the spread of catastrophes such as fire and disease, and the creation of an edge habitat occupied by a large number of predators. The authors conclude that conservation resources may be better spent on additional high-quality refugia and development of more environmentally-friendly resource use on multiple use lands.

landscape-level, landscape patterns, corridors, biodiversity, fragmentation, ecosystem management, natural areas, special sites.

1133. Simmons, M. A.; Cullinan, V. I.; Thomas, J. M. 1992. **Satellite imagery as a tool to evaluate ecological scale.** Landscape Ecology. 7: 77-85.

landscape-level, scale, remote sensing, ecosystem.

1134. Simpson, J. W.; Boerner, R. E. J.; DeMers, M. N.; Berns, L. A.; Artigas, F. J.; Silva, A. 1994. **Forty-eight years of landscape change on two contiguous Ohio landscapes.** Landscape Ecology. 9: 261-270.

Two contiguous rural landscapes covering about $240km^2$ in central Ohio, one a homogeneous till plain and the other a moraine landscape with greater heterogeneity, were compared by analyzing aerial photographs from 1940, 1957, 1971, and 1988. Information from historical archives was used with the photographs to classify and delineate landscape types, such as upland forest, young woodland, riparian forest, agriculture, urban/suburban, etc. Photos were manually interpreted, and mapping of the 1988 photographs ground-truthed to determine accuracy of interpretation. Polygons were transferred to mylar overlays and digitized into an ARC/INFO GIS system. The two areas were compared for number, cover, size, shape, and diversity of landscape units.

landscape-level, landscape planning, pattern, landscape change, pattern, regional planning, cover typing, habitat mapping, vegetation mapping, large-scale monitoring, monitoring examples, detecting change, aerial photography, cover, GIS.

1135. Sinclair, R. 1986. **The T.G.B. Osborne vegetation reserve at Koonamore: long-term observations of changes in arid vegetation.** In: Joss, P. J.; Lynch, P. W.; Willians, O. B., eds. Rangelands: a resource under seige -- proceedings 2nd International Rangeland Congress; Canberra, Australia. Canberra, Australia: Australian Academy of Science: 67-68.

long-term ecological monitoring, community change, community-level, rangeland, desert, general examples, special sites, detecting change.

1136. Singh, J. S.; Lauenroth, W. K.; Steinhorst, R. K. 1975. **Review and assessment of various techniques for**

estimating net aerial primary production in grasslands from harvest data. Botanical Review. 41: 181-232.

field techniques, production, technique comparison, grassland.

1137. Skalski, J. R. 1987. **Selecting a random sample of points in circular field plots**. Ecology. 68: 749.

sampling design, design, plot selection, random sampling.

1138. Skalski, J. R.; McKenzie, D. H. 1982. **A design for aquatic monitoring programs**. Journal of Environmental Management. 14: 237-251.

Aquatic monitoring for nuclear power plant development has been a common activity since the passage of NEPA (National Environmental Policy Act), but reviews of monitoring implemented in the 1970s suggest that most programs were not designed to statistically detect changes in biota. The author recommends the use of the control-treatment pairing (CTP) design, which compares the mean difference between paired treatment and control site(s) over a pre-perturbation period to that occurring afterward (also called the Before-After-Control-Impact (BACI) design). Specific design issues include identifying the response variable(s) and specifying the minimal amount of change that must be detected by the monitoring program--the size of the change thought important and the Type I and Type II error rates. These monitoring objectives, however, may be difficult to meet due to the temporal and spatial variability of the system and constraints on monitoring time and effort. A framework for aquatic monitoring designs and examples are provided.

monitoring examples, aquatic, experimental design, sampling design, detecting change, disturbance, large-scale monitoring, power, precision, Type I and Type II errors, BACI, design.

1139. Skovlin, J. M.; Thomas, J. W. 1995. **Interpreting long-term trends in Blue Mountain ecosystems from repeat photography**. Gen. Tech. Rep. PNW-315. Portland, OR: U.S. Deparment of Agriculture, Forest Service, Pacific Northwest Research Station. 102 p.

field techniques, photopoints, long-term ecological monitoring, monitoring examples.

1140. Slayter, R. O., ed. 1977. **Dynamic changes in terrestrial ecosystems: patterns of change, technique for study and application to management**; 1976 January 12-16; Santa Barbara, CA. Tech. Notes 4. Paris: United Nations Educational, Scientific and Cultural Organization. 30 p.

This paper summarizes the thoughts of participants in a workshop on dynamic changes in ecological systems, techniques available for their study, and application of these concepts and techniques to basic ecological research and management of natural ecosystems. A brief discussion of ecological succession and disturbance is provided. Techniques listed for analysis of four general data types (surveys, experiments, system analysis and models, and Markov Chains) are illustrated with schematics. Modelling and Markov chains are discussed in detail.

community change, succession, analysis, trend analysis, ecological processes, analysis, community-level, ecological models.

1141. Slob, W. 1986. **Strategies in applying statistics in ecological research**. Amsterdam, Netherlands: Free University Press. 112 p.

This short book contains 3 chapters applicable to analysis of ecological data. In the first, 3 analyses are compared: parametric analysis with and without transformation and nonparametric analysis. The author argues that nonparametric approaches are inadequate since they only furnish p-values, but no information on the power of the test. They also fail to provide information on changes in variability because their focus is on changes in location (mean). Many of the common tests even assume homogeneity of variances, an assumption often violated by ecological data but rarely tested. Parametric approaches are based on the assumption that sources of variation operate additively, but most ecological processes appear multiplicative. If so, transformation is appropriate, but many ecologists resist data transformations because of the difficulty in interpreting back-transformed mean and confidence intervals. The author advocates logarithmic transformation of the data before treatment with standard parametric techniques. Backtransformed data can be interpreted in terms of the median rather than the mean, an approach more appropriate to lognormal distributions. The third chapter describes the use of statistical power analysis. The author argues defining the strength of the effect in terms of residual variation in F-tests (relative effect size index) is less appropriate for ecological studies than the calculation of an absolute effect size index. The procedures needed to calculate this index for an ANOVA model are presented.

power, precision, ANOVA, confidence intervals, nonparametric statistics, parametric statistics, statistical interpretation, analysis, statistics overview, Type I and Type II errors, design.

1142. Slonim, M. J. 1960. **Sampling: a quick, reliable guide to practical statistics**. New York, NY: Simon and Schuster. 144 p.

statistics overview, analysis, sampling design, design.

1143. Smartt, P. F. M. 1978. **Sampling for vegetation survey: a flexible systematic model for sample location**. Journal of Biogeography. 5: 43-56.

Sampling designs can be extrinsic, in which a random or systematic sampling pattern is independent of the vegetation patterns, or intrinsic, with sampling units subjectively placed relative to apparent vegetation patterns. Because of the bias inherent in the latter most investigators have chosen the former, but this may distribute sampling units inefficiently, with a high percentage of the sampling units allocated to large areas of homogeneous vegetation, providing little new

information. Preferably, areas of greatest vegetation heterogeneity would be sampled most intensively. In the method described here, a grid is established in the sampling area and a proportion of the plots used as initial sampling points. Additional plots are allocated to the interstices of the grid based on the diversity or floristic differentiation between adjacent initial plots. A test of the flexible method in a marsh ecosystem demonstrated that not only did the method produce data that captured more of the predefined cover types at the site, but it also allowed for more accurate mapping of vegetation in areas of high diversity compared to aerial photo interpretation.

community composition, community classification, cover typing, plant associations, vegetation mapping, wetland, plot selection, sampling design, community-level, design, plot selection.

1144. Smartt, P. F. M.; Grainger, J. E. A. 1974. **Sampling for vegetation survey: some aspects of the behavior of unrestricted and stratified techniques**. Journal of Biogeography. 1: 193-206.

Stratified random sampling was found to exhibit greater overall accuracy compared to random or systematic sampling.

sampling design, random sampling, systematic sampling, stratified sampling, design, plot selection.

1145. Smartt, P. F. M.; Meacock, S. E.; Lambert, J. M. 1974. **Investigation into the properties of quantitative vegetational data. I. Pilot study**. Journal of Ecology. 62: 735-759.

community-level, community composition, community change.

1146. Smartt, P. F. M.; Meacock, S. E.; Lambert, J. M. 1976. **Investigations into the properties of quantitative vegetational data. II. Further data type comparison**. Journal of Ecology. 64: 41-78.

community-level, community classification, community composition, field techniques, technique comparison.

1147. Smith, A. D. 1944. **A study of the reliability of range vegetation estimates**. Ecology. 25: 441-443.

A crew of 8 observers visually estimated the cover in a $100ft^2$ plot in 3 range vegetation types. Estimates were repeated on the same plot 3 times in one day, and a new set of plots were estimated each day. The first day's plots were re-estimated on the fourth and seventh day. During the first 4 days, the observers were allowed to discuss their estimates on training plots (these were not included in the analysis). Over time, the group average declined, and on the final day was 72% or less of the first day's estimates of cover. The group also became more uniform, but in some comparisons, the highest cover estimate was more than twice the lowest. Variation between estimates made in the same day was often significant, suggesting the inability of an observer to repeatedly assign the same cover value to a plot. Some individuals were consistently below or above the group mean, while others varied erratically. There was also poor correlation between estimated cover and actual clipped weight of the plot.

field techniques, cover, cover classes, canopy cover, ocular estimation, observer variability, rangeland, technique comparison, production.

1148. Smith, D. R. 1968. **Bias in estimates of herbage utilization derived from plot sampling**. Journal of Range Management. 21: 109-110.

field techniques, utilization, production.

1149. Smith, D. A.; Schmutz, E. M. 1975. **Vegetative changes on protected versus grazed desert grassland ranges in Arizona**. Journal of Range Management. 28: 453-458.

community-level, community change, rangeland, grassland, herbaceous species, general examples.

1150. Smith, E. P.; Orvos, D. R.; Cairns, J., Jr. 1993. **Impact assessment using the before-after-control-impact (BACI) model: concerns and comments**. Canadian Journal of Fisheries and Aquatic Sciences. 50: 627-637.

design, BACI, statistical interpretation, biological significance, detecting change, analysis, community change.

1151. Smith, J. G. 1962. **An appraisal of the loop transect method for estimating root crown area changes**. Journal of Range Management. 15: 72-78.

field techniques, cover, loop frames, basal area.

1152. Smith, M. P. L. 1991. **Environmental impact assessment: the roles of predicting and monitoring the extent of impacts**. Australian Journal of Marine and Freshwater Research. 42: 603-614.

objectives, predicting change, monitoring and management, ecological models, monitoring overviews.

1153. Smith, N. J.; Iles, K. 1988. **A graphical depiction of multivariate similarity among sample plots**. Canadian Journal of Forest Research. 18: 467-472.

analysis, multivariate analysis, graphical analysis.

1154. Smith, S. D. 1982. **Evaluation of the frequency plot method as an improved technique for measuring successional trend**. Moscow, ID: University of Idaho. 95 p. Thesis.

field techniques, frequency, rangeland, community-level, community change, succession.

1155. Smith, S. B., ed. 1982. **Symposium on environmental monitoring**. Edmonton, Alberta: Alberta Society of Environmental Biologists. 259 p.

general book on monitoring, monitoring overviews, aquatic.

1156. Smith, S. D.; Bunting, S. C.; Hironaka, M. 1986. **Sensitivity of frequency plots for detecting vegetation change**. Northwest Science. 60: 279-286.

The authors simulated changes in vegetation by constructing exclusion areas of 20x50cm, in which the vegetation was assumed not to exist, to represent changes of 10%, 20%, and 30%. Vegetation was sampled using ten 10m transects with 40 nested plots along each transect. The sensitivity of the design for measuring changes (tested with a chi^2 test- each plot representing a repeated sample) was determined for each level of change.

field techniques, community change, community-level, frequency, nested frequency, precision, detecting change.

1157. Smith, T.; Huston, M. 1989. **A theory of spatial and temporal dynamics of plant communities**. Vegetatio. 83: 49-69.

community-level, community change, succession.

1158. Snedecor, G. W.; Cochran, W. G. 1989. **Statistical methods. 8th ed.** Ames, IA: Iowa State University Press. 524 p.

analysis, statistics overview.

1159. Sokal, R. R.; Rohlf, F. J. 1981. **Biometry**. San Francisco, CA: Freeman and Co. 859 p.

This book is one of the standard biostatistics texts used in ecological and biological studies. The book is designed for graduate students and researchers, but makes no assumptions about previous statistical knowledge. The style is more informal and textual than many statistical books, a deliberate attempt on the part of the authors to make the material accessible to readers as well as students using this as a text. Although the book is well sprinkled with formulas, the authors contend that the relatively simple mathematical steps should not intimidate those with limited mathematical skills. A key value of the book as a reference is a table on the frontispiece that refers the reader to the proper test or procedure based on the number of variables and samples, the purpose of the analysis, and the type of measurement variable. The table refers to boxed examples found within the text that completely illustrate each procedure. One drawback to the book is the lack of statistical tables, but a companion volume of tables is available.

analysis, statistics overview.

1160. Solomon, A. M.; Shugart, H. H., eds. 1993. **Vegetation dynamics and global change**. New York, NY: Chapman and Hall. 338 p.

global change monitoring, succession, predicting change, community change, landscape change, landscape-level, community-level.

1161. Solow, A. R. 1993. **A simple test for change in community structure**. Ecology. 62: 191-193.

A common monitoring strategy is to draw a sample of from the community before and after a disturbance, or over time, and compare changes in an index of diversity calculated from this sample. Since differences can arise by sampling error alone, it is important to assess the significance of observed changes. A randomization test can determine the distribution of the index under the null hypothesis that the two samples were drawn from the same population (no change in community composition). The significance of the observed value of the index can then be evaluated in relation to the distribution of the values found by randomization. An example is provided.

community-level, design, analysis, detecting change, biodiversity, community composition, diversity indices, randomization tests, community change.

1162. Solow, A. R.; Broadus, J. M.; Tonring, N. 1993. **On the measurement of biological diversity**. Journal of Environmental and Economic Management. 24: 60-68.

landscape-level, biodiversity, community-level, diversity indices, species diversity, community composition.

1163. Somers, P.; Nichols, G. E.; Stransky, R. W. 1980. **Baseline ecological study of Narraguinnep Research Natural Area, San Juan National Forest.** Final Rep. Durango, CO: Fort Lewis College. 6 p.

monitoring examples, baseline monitoring, natural areas, special sites.

1164. Sondheim, M. W. 1978. **A comprehensive methodology for assessing environmental impact**. Journal of Environmental Management. 6: 27-42.

objectives, detecting change, design.

1165. Soplin, H.; Gross, H. D.; Rawlings, J. D. 1975. **Optimum size of sampling unit to estimate coastal bermudagrass yield**. Agronomy Journal. 67: 533-537.

field techniques, production, biomass, plot dimensions, precision, sampling design, sample size.

1166. Soule, M. E.; Alberts, A. C.; Bolger, D. T. 1992. **The effects of habitat fragmentation on chaparral plants and vertebrates**. Oikos. 63: 39-47.

landscape-level, desert, shrubland, fragmentation, pattern.

1167. Sparks, R. E. 1987. **Improving methods of data analysis and interpretation for environmental management programs**. In: Draggan, S.; Cohrssen, J. J.; Morrison, R. E., eds. Environmental monitoring, assessment, and management: the agenda for long-term research and development. New York, NY: Praeger Publishers: 37-48.

Two types of programs, those studying ecological system function (primarily academic) and those concerned with the status of systems and progress toward management goals (resource agencies), are often not linked. This is unfortunate because agencies need to understand system function in order to interpret monitoring data on the status of parts or aspects of the system. Additionally, long-term monitoring data sets could enhance the academic pursuit of understanding

systems. Good interpretation of monitoring data is also needed to identify useful indicators of ecosystem health. Information on successful monitoring is difficult to access, although the Ecosystems Center at Cornell reviews literature and databases to determine useful indicators or measures. The author makes several recommendations: 1) foster exchange between people involved in understanding biotic systems and those charged with gathering and interpreting monitoring data; 2) use workshops to bring together regulatory, management, scientific, and advocacy communities to analyze data sets and determine adequacy of monitoring, effective alternatives, and effective presentation; and 3) make data sets and models available to interest groups and other agencies to encourage use of the data and solicit criticism on design.

monitoring examples, ecological monitoring programs, biological significance, monitoring and management, resource management, long-term ecological monitoring, ecosystem management.

1168. Spedding, C. R. W.; Large, R. W. 1957. **A point-quadrat method for the description of pasture in terms of height and density**. Journal of The British Grassland Society. 12: 229-234.

community-level, grassland, community composition, field techniques, frequency, cover, density, heights.

1169. Spellerberg, I. F. 1991. **Monitoring ecological change**. New York, NY: Cambridge University Press. 334 p.

This book is one of few specifically devoted to ecological monitoring. The first few chapters describe the reasons and importance of monitoring, and current activities around the world. The second part provides information on general approaches, including chapters on indicators, use of diversity and similarity indices, and a discussion of scale and habitat differences. The last part includes a chapter on planning a monitoring project, and chapters specifically addressed to monitoring birds, freshwater systems, nature preserves, landscapes, and rare species. A chapter on the relationship of environmental impact assessment and monitoring is also included.

monitoring examples, general book on monitoring, monitoring overviews, ecological monitoring programs, environmental monitoring programs, large-scale monitoring, long-term ecological monitoring, protected areas, special sites, community-level, landscape-level, objectives, monitoring and management, fragmentation, indicators, landscape planning, landscape change, scale, community composition, community change, diversity indices, species diversity.

1170. Spitzer, D. 1986. **On applications of remote sensing for environmental monitoring**. Environmental Monitoring and Assessment. 7: 263-272.

remote sensing, monitoring examples, large-scale monitoring.

1171. Sprugel, D. G. 1991. **Disturbance, equilibrium, and environmental variability: what is 'natural' vegetation in a changing environment?** Biological Conservation. 58: 1-18.

A brief history of North American thought on 'natural' conditions, climax, and natural disturbance demonstrates some of the intellectual baggage often brought to debates about what is natural. A popular current model is one of equilibrium on a large or landscape scale with changing patches within that landscape due to disturbance. This model requires consideration of scale in designing monitoring studies, because small, permanent representative plots may not be representative of the landscape over time. While this model may describe some systems well, the author uses four examples to demonstrate that by failing to consider long enough time spans, non-equilibrium systems may be mistaken for equilibrium ones. This can be caused by the spatial scale of disturbance (so large in scale that the disturbance affects the entire landscape), the effects of unique past events (such as the appearance of a pathogen), and climate variability. Much of the current old-growth Pacific forests, for example, may have established during a warm period between 1000 to 1300 AD, as a result of increased fire frequency. In addition, these forest are a maximum of 6000 years old, only 5 to 10 Douglas-fir life spans and likely too short a period to reach equilibrium. Our time frame of observation is generally too short, especially in systems dominated by long-lived vegetation, to understand the dynamics of the changes. These long-term dynamics make it difficult to identify an optimal "natural condition" for a site. In reality, the range of natural conditions for a particular site is likely much broader than we imagine.

special sites, natural areas, national parks, natural areas, ecological models, objectives, wilderness, landscape-level, disturbance, ecological processes, ecosystem, ecosystem management, pattern, landscape change, patch dynamics, scale, community-level, community composition, community structure, community change, predicting change, succession, coniferous forest, deciduous forest, woodland, forest, long-term ecological monitoring, natural variability.

1172. Stafford, S. G. 1993. **Data, data everywhere, but not a byte to read: managing monitoring information**. Environmental Monitoring and Assessment. 26: 125-143.

The Forest Science Data Bank (FSDB) is a system designed to deal with over 2400 data sets from more than 350 existing studies associated with the Andrews Long-Term Ecological Research (LTER) program. Six features are important for successful database creation and use: 1) involvement of users in the scientific community; 2) standardize documentation describing data sets; 3) a system of data quality assurance; 4) security; 5) easy data access and retrieval; and 6) flexibility in data export/import.

design, data management, monitoring examples, long-term ecological monitoring.

1173. Stage, A. R.; Rennie, J. C. 1994. **Fixed-radius plots or variable-radius plots?** Journal of Forestry. 92(12): 20-24.

The relationship between fixed and variable-radius plots becomes clearer if one thinks in terms of the zone of influence around a tree, and the probability that the sample point will fall within that zone. For variable-radius plots, the zone of influence varies with the basal area of the tree. For fixed plots, the zone is the same regardless of tree size. Variable-radius plots are more efficient for estimating basal area because the variance among trees of the ratio of basal area to zone of influence is zero. Similarly, fixed plots are more efficient at measuring frequency because the variance of the frequency (unity for a single tree) to the zone of influence is zero. While field efficiencies would seem better for variable plots (since basal area is estimated by counting trees rather than measuring distances or DBH), in stands of large trees the distance from the tree to the sample point limits clear ocular decisions on whether the tree is "in" or "out," requiring more detailed distance measures and increased chance of missing large trees that should be included in the count. In addition, small trees have such small areas of influence that counts are often biased by edge effect. The key draw-back of fixed plots is that the plot size is not optimal for all densities, unlike the variable plot which adjusts automatically to changes in density associated with different diameter size classes. A design that combines fixed plots for very large and very small trees with variable plots for moderately sized trees may reduce problems associated with variable radius sampling.

field techniques, density, forest, variable plots, basal area, tree, sampling design, frequency.

1174. Stalter, A. M.; Whitmore, M. C.; Krasny, M. E. 1994. **Comparison of methods for measuring and describing forest gaps in central New York**. Bulletin of the Ecological Society of America. 75: 218.

landscape-level, disturbance, patch dynamics, coniferous forest, deciduous forest, forest, field techniques, technique comparison.

1175. Stampfli, A. 1991. **Accurate determination of vegetational change in meadows by successive point quadrat analysis.** Vegetatio. 96: 185-194.

community-level, community change, meadow, grassland, point intercept, detecting change.

1176. Stankey, G. H.; Cole, D. N.; Lucas, R. C.; Petersen, M. E.; Frissell, S. S. 1985. **The limits of acceptable change (LAC) system for wilderness planning**. Gen. Tech. Rep. INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 37 p.

special sites, wilderness, objectives, monitoring overviews.

1177. Stanton, F. W. 1960. **Ocular point frame**. Journal of Range Management. 13: 153.

field techniques, cover, point intercept, point frames, tools.

1178. Steele, R. G. D.; Torrie, J. H. 1980. **Principles and procedures of statistics: a biometrical approach. 2nd ed**. New York, NY: McGraw-Hill. 633 p.

statistics overview, analysis.

1179. Steffen, W. L. 1996. **A periodic table for ecology? A chemist's view of plant functional types**. Journal of Vegetation Science. 7: 425-430.

functional groups, community-level, community composition.

1180. Stein, W. I. 1995. **Ten-year development of Douglas-fir and associated vegetation after different site preparation on Coast Range clearcuts**. Res. Pap. PNW-473. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 115 p.

succession, community-level, community change, monitoring examples, community-level, tree, forest, design.

1181. Stephenson, S. N.; Buell, M. F. 1965. **The reproducibility of shrub cover sampling**. Ecology. 46: 379-380.

field techniques, cover, line intercept, shrub.

1182. Stern, P.; Ashton, P. 1995. **Botanical surveys for conservation and land management**. New York, NY: Chapman and Hall. 224 p.

inventory, species lists, rare species.

1183. Stevens, D. L. 1994. **Implementation of a national monitoring program**. Journal of Environmental Management. 42: 1-29.

monitoring examples, large-scale monitoring, ecological monitoring programs.

1184. Stevens, R. 1986. **Population dynamics of two sagebrush species and rubber rabbitbrush over 22 years of grazing use by three animal classes**. In: McArthur, E. D.; Welch, B. L., comps. Proceedings-- symposium on the biology of *Artemisia* and *Chrysothamnus*; 1984 July 9-13; Provo, UT. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 278-285.

A five-way exclosure, eliminating grazing of various combinations of deer, cattle, and rabbits, was monitored for over 20 years following chaining of pinyon-juniper and seeding. In each 45x45m exclosure treatment, 5 permanent 30.5m transects were randomly located. Cover was measured along the transect with 200 point intercepts. All shrubs within each treatment area were mapped and classed to size. The number of rabbitbrush shrubs in all size classes under no grazing and combinations of native mammal grazing increased dramatically from 1964 to 1973 and then decreased in 1984 (from an average of 2 individuals in the middle size class in 1964, to 119 in 1973, to 19 in 1984; one treatment went from 7 individuals in 1964 to 218 in 1973). Basin big sagebrush plants generally increased between 1964 and 1984

in the largest size class (as much as a 50% increase), but increased and then declined dramatically in the middle size class (averaged across the four treatments: 8 individuals in 1964, 244 in 1973, and 26 in 1984). In the area accessible to cattle, shrub numbers of both species showed a steady increase between 1963 and 1984. An important implication of this study is that the design, even though there was no replication, allowed some biological interpretation of changes due to weather and grazing. A second implication is that changes can be dramatic over time even for relatively long-lived species such as rangeland shrubs; this variability over time makes it difficult to set vegetation objectives and develop effective monitoring.

objectives, predicting change, biological significance, community composition, community structure, rangeland, shrub grassland, density, point intercept, canopy cover, natural variability, shrub, community change, community-level, shrubland, rangeland, cover.

1185. Stewart-Oaten, A. 1995. **Rules and judgements in statistics: three examples**. Ecology. 76: 2001-2009.

biological significance, adaptive management, analysis, statistical interpretation.

1186. Stewart-Oaten, A.; Bence, J. R.; Osenberg, C. W. 1992. **Assessing effects of unreplicated perturbations: no simple solutions.** Ecology. 73(4): 1396-1404.

A replicated design is rare for large scale ecological studies or environmental impact studies, usually limited by the cost or by the opportunity (e.g., only one impact site, such as a power plant). The objective of such studies is to determine whether the perturbed system differs significantly from what it would have been in the absence of disturbance. The BACIP design (before-after-control-impact-pairs) uses several paired measurements taken at a control site and at the impact site before and after the perturbation. The mean observed differences between the two sites are compared before and after. Statistical analysis of the data, however, can be difficult. Assumptions of two-sample tests may not be met: identical normal distributions (normal with equal variances), independence, and additivity. Here, the randomization t-test (the approach used in randomized intervention analysis in Carpenter and others 1989), the standard parametric t-test, and Welch's t-test are compared. The authors conclude that 1) there is no advantage to the randomization test compared to the two t-tests for non-normal data unless the sample sizes are very small; 2) the Welch's t-test is approximately valid when the before and after distributions have different variances, while the other two are not; 3) the Welch's t-test is approximately valid when the distributions vary within a period, while the other two are not unless the average before variance is close to the average after variance; 4) if the successive differences are correlated (lack independence), none of the tests are valid; and 5) if time and location effects are not additive, none of the tests are valid. Serial correlation can be tested with the Durbin-Watson and Ljung-Box tests, and a one-way ANOVA. Non-additivity can sometimes be addressed through transformations or use of more robust estimators (biweight estimators, trimmed means, modified maximum likelihood estimators) and their associated "t-like" tests. A final subject addressed is that of standard hypothess testing compared to Bayesian. The authors prefer neither, recommending instead standard confidence interval analysis. They argue the main statistical task is not to test hypotheses, but to estimate effect size and estimate the precision of these estimates, a task best met by confidence interval analysis.

BACI, detecting change, precision, disturbance, experimental design, confidence intervals, analysis, design, disturbance, ANOVA.

1187. Stewart-Oaten, A.; Murdoch, W. R.; Parker, K. R. 1986. **Environmental impact assessment: "pseudoreplication" in time?** Ecology. 67: 929-940.

design, BACI, pseudoreplication, detecting change.

1188. Stewart, G.; Hutchings, S. S. 1936. **The point-observation-plot (square foot density) method of vegetation survey**. Journal of The American Society of Agronomy. 28: 714-722.

rangeland, grassland, field techniques, frequency, cover, density.

1189. Stewart, G. H.; Johnson, P. N.; Mark, A. F. 1989. **Monitoring terrestrial vegetation for biological conservation**. In: Craig, B., ed. Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on protected natural areas; 1988 May; Dunedin. Wellington: Department of Conservation: 199-208.

Vegetation monitoring in New Zealand by government conservation departments was initiated in the 1950s. Experience from these and later projects can be summarized in the following points: 1) objectives must be clearly defined; 2) methods must be appropriate to objectives and vegetation types; 3) sites for monitoring must be selected carefully; 4) an appropriate sampling strategy must be designed; 5) field markings should be adequate for relocating plots and transects, and should be checked periodically to guard against loss; 6) location, objectives, methods, and recording format should be detailed in the establishment report so that remeasurements are possible years later; 7) monitoring frequency will be dictated by the objectives, the rate of change, and the resources available; 8) physical impacts to the site should be minimized; and 9) personnel conducting the measurements must be well-trained and committed to careful data collection. Eight monitoring case studies are presented: deer impact on coastal forests, dieback in beech forests, deer impact on tussock grasslands, fire effects on tussock grasslands, impact of roads on alpine tundra, fire effects in a lowland bog, effects of gulls on a lowland bog, and the effects of water level changes on lakeshore vegetation.

objectives, monitoring overviews, alpine, wetland, deciduous forest, grassland, aquatic, permanent plots, data management, monitoring examples.

1190. Stickney, P. F. 1985. **Data base for early postfire succession on the Sundance Burn, northern Idaho**. Gen. Tech. Rep. INT-189. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 121 p.

community-level, community change, forest, succession, prescribed fire, permanent plots, long-term ecological monitoring.

1191. Stickney, P. F. 1990. **Early development of vegetation following holocaustic fire in northern Rocky Mountain forests**. Northwest Science. 64(5): 243-246.

general examples, forest, permanent plots, succession, disturbance.

1192. Stine, P. A.; Davis, F. W.; Csuti, B.; Scott, J. M. 1996. **Comparative utility of vegetation maps of different resolutions for conservation planning**. In: Szaro, R. C.; Johnson, D. W., eds. Biodiversity in managed landscapes. New York, NY: Oxford University Press: 210-220.

Gap analysis involves use of relatively coarse distribution maps of species and communities to identify biodiversity "hot spots" and to determine gaps in the protection of elements of diversity. The minimum mapping unit is 100ha polygons in which primary and secondary vegetation types are visually identified from Landsat Thematic Mapper imagery. A gap analysis map of California coastal sage scrub vegetation was compared to a map prepared by visual interpretation of 1:48,000 color aerial photography. Overlap between the two maps was good for larger contiguous areas of sage scrub, although 13 polygons were misclassified on the gap map as urban or agricultural use, suggesting a possible bias. As expected, the gap map failed to identify small areas of sage scrub. Although most of these fragmented or isolated areas would not be good candidates for protection as core areas, the gap map missed most of the low elevation shrub sage sites intermixed with development. These may be significant as habitat for endemic plant species, or as connections to larger areas. The conclusion is that gap analysis, a coarse filter approach, must be supplemented by local, more detailed maps and ground surveys.

natural areas, biological significance, biodiversity, fragmentation, habitat management, landscape planning, pattern, patch dynamics, pattern, regional planning, scale, community composition, Landsat, TM, remote sensing, aerial photography, vegetation mapping, landscape-level, community-level.

1193. Stohlgren, T. J. 1995. **Planning long-term vegetation studies at landscape scales**. In: Powell, T. M.; Steele, J. H., eds. Ecological time series. New York, NY: Chapman and Hall: 209-241.

This chapter provides an excellent literature review and framework for planning long-term vegetation studies at landscape scales. The author reviews past and current long-term vegetation studies, and discusses their limitations for inferring vegetation pattern and changes over larger landscapes. He presents a conceptual framework for developing long-term vegetation studies which considers goals, objectives, scale, sampling design, intensity of sampling, and pattern of sampling (GOSSIP). The author uses two new vegetation studies (global change and biodiversity) currently underway at Rocky Mountain National Park to illustrate application of the framework. The author suggests utility of individual long-term vegetation studies may be improved by seeking greater consistency in study design and methods. This paper is valuable to anyone interested in designing a long-term vegetation monitoring project.

objectives, sampling design, scale, global change monitoring, biodiversity, detecting change, large-scale monitoring, long-term ecological monitoring, landscape change, sampling design, national parks, monitoring examples, special sites, landscape-level, design, monitoring overviews.

1194. Stohlgren, T. J.; Binkley, D.; Veblen, T. T.; Baker, W. L. 1995. **Attributes of reliable long-term landscape-scale studies: malpractice insurance for landscape ecologists**. Environmental Monitoring and Assessment. 36: 1-25.

Drawing from the literature and personal experience, the authors identify a framework of 14 attributes to guide development and implementation of reliable long-term landscape monitoring programs. They recognize that sampling techniques at the plot-to-stand level in homogeneous conditions may not be appropriate at landscape scales. Planning long-term landscape studies is made difficult by the scale of some disturbances (e.g. fire, insect outbreaks) which exceed typical study area sizes, and the variability of responses to disturbances. To guide others in planning landscape studies, the authors present a discussion on how a current landscape level vegetation study (Colorado Rockies Global Change Research Program) relates to each of the 14 identified attributes.

landscape-level, long-term ecological monitoring, permanent plots, special sites, national parks, scale, ecotones, landscape change, monitoring examples, objectives, global change monitoring, ecological monitoring programs.

1195. Stohlgren, T. J.; Coughenour, M. B.; Chong, G. W.; Binkley, D.; Kalkhan, M. A.; Schell, L. D.; Buckley, D. J.; Berry, J. K. [In press]. **Landscape analysis of plant diversity**. Landscape Ecology.

Landscape-scale Gap Analysis described in this paper is a prototype effort to link traditional Gap Analysis (broad scale data) with ecological data at finer levels of resolution and scales useful to resource managers. Attention is focused on "keystone ecosystems" (those that contain high plant species richness or distinctive species composition), which are

missed or under-represented in the broader scale surveys. Landscape-scale Gap Analysis uses a fine-filter approach to link vegetation data from landscape level to plots, and wildlife data at a variety of population levels. This prototype effort is being conducted within and adjacent to Rocky Mountain National Park, Colorado.

pattern, biodiversity, inventory, national parks, scale, species richness, GIS, ecological models, landscape-level, rare species, ecosystem management, monitoring examples, large-scale monitoring.

1196. Stohlgren, T. J.; Falkner, M. B.; Schell, L. D. 1995. **A modified-Whittaker nested vegetation sampling method**. Vegetatio. 117: 113-121.

This paper presents a Modified-Whittaker plot design developed by the authors to minimize statistical problems associated with the original Whittaker plot (Smida 1984). Although the base plot (20x50m) remains the same, the new design minimizes subplot overlap, and through use of consistent rectangle proportions, removes subplot size-shape interactions. The authors compare multi-scale species richness patterns determined from the two designs on 32 sites with forest and prairie vegetation (including 7 ecotones). The Modified-Whittaker yielded significantly higher species richness values for all subplot sizes. The original Whittaker plot underestimated plant species richness by 34%, whereas the modified design underestimated plant species richness by only 9%. Species-area relationships between the two designs were also examined. The Modified-Whittaker design explained, on average, 92% of the variation. The authors provide diagrams and descriptions of plot layout and design.

ecotones, sampling design, plot dimensions, species diversity, species richness, technique comparison, field techniques, cover, design, forest, grassland.

1197. Stone, E. C. 1965. **Preserving vegetation in parks and wilderness**. Science. 150: 1261-1267.

special sites, objectives, national parks, wilderness.

1198. Stout, B. B. 1993. **The good, the bad and the ugly of monitoring programs: defining questions and establishing objectives**. Environmental Monitoring and Assessment. 26: 91-98.

The key challenge of monitoring is to measure rates of change in an ecological system and determine if those rates are normal or abnormal. The time frame for separating normal variation from trend can be very long but maintaining a consistent monitoring program over the long term is difficult. A good monitoring program 1) retains long-term support; 2) has clear objectives and rigorous plans for analysis; 3) encompasses variation at large, intermediate, and small scales; and 4) should be designed to test the null hypothesis that changes are not abnormal and not due to man's activities.

monitoring and management, long-term ecological monitoring, objectives, monitoring overviews, biological significance, natural variability.

1199. Strand, G. 1996. **Detection of observer bias in ongoing forest health monitoring programmes**. Canadian Journal of Forest Research. 26: 1692-1696.

In the Norwegian forest health monitoring program, crown density is a key component for assessing changes in forest health. Crown density is the ocular assessment of the amount of live needles remaining on a tree compared to a healthy tree. This paper reports that observer bias can be a serious problem, resulting in artificial geographical patterns of change when surveying teams operate regionally. The authors suggest that permanent assignment of teams to monitoring sites may reduce the problem.

monitoring examples, large-scale monitoring, ecological monitoring programs, long-term ecological monitoring, forest, coniferous forest, deciduous forest, field techniques, observer variability, tree.

1200. Strayer, D.; Glitzenstein; J. S.; Jones, C. G.; Kolasa, J.; Likens, G. E.; McDonnel, M. J.; Parker, G. G.; Pickett, S. T. A. 1986. **Long-term ecological studies: an illustrated account of their design, operation, and importance to ecology**. The Institute of Ecosystem Studies Occasional Publ. 2. New York, NY: The New York Botanical Garden. 28 p.

Through information gathered from questionnaires, site visits, and interviews the authors provide a detailed narrative account of the features of long-term studies. They present this discussion and information with the hope that it will result in better long-term studies. The authors discuss the values of long-term studies and emphasize their importance in understanding certain types of ecological phenomena including slow processes, rare events, subtle processes, and complex phenomena. Some of the other topics addressed are: 1) attributes of successful long-term studies; 2) relationships between short-term and long-term studies; and 3) design and data management considerations. This paper is essential reading for anyone who is planning on initiating a new long-term study.

long-term ecological monitoring, design, data management, sampling design, objectives, monitoring overviews, monitoring and management.

1201. Stromberg, M. R.; Griffin, J. R. 1996. **Long-term patterns in coastal California grasslands in relation to cultivation, gophers, and grazing**. Ecological Applications. 6(4): 1189-1211.

monitoring examples, grassland, community-level, community change.

1202. Strong, C. W. 1966. **An improved method of obtaining density from line-transect data**. Ecology. 47: 311-313.

field techniques, density, line intercept.

1203. Stroup, W. W.; Stubbendieck, J. 1983. **Multivariate statistical methods to determine changes in botanical composition**. Journal of Range Management. 36: 208-212.

This paper describes analysis of an experiment in which there are two or more treatments, replicates (blocks), and number of remeasurements (time). If there is only a single variable of interest, these experiments may be analyzed by an ANOVA if each of the error terms is normally distributed with a constant variance for each treatment-block-time combination (an assumption that is often violated). In most cases, the ANOVA model is not appropriate because the percent composition of a number of species is what is of interest. Since the sum of all proportions must be equal to 1.0, the percent composition of each species is obviously negatively correlated with that of others. This design is properly analyzed by a multivariate analysis of variance (MANOVA) provided certain assumptions are met. Careful sampling design and adequate sample size can control for the assumption of normally distributed error terms. The authors suggest that an adequate sample size will require a least several hundred points sampled with a 10-point frame in most short and mid-grass vegetation types.

community composition, community change, grassland, point frames, point intercept, cover, ANOVA, MANOVA, repeated measures analysis, analysis, sample size, sampling design, design, field techniques, community-level.

1204. Stuart, A. 1976. **Basic ideas of scientific sampling. Second edition**. London: Charles Griffen. 106 p.

design, sampling design.

1205. Sudia, T. W. 1954. **A comparison of forest ecological sampling techniques with the use of a known population**. Columbus, OH: Ohio State University. Dissertation.

forest, sampling design, design, technique comparison, field techniques.

1206. Sugihara, G.; Grenfell, B.; May, R. M. 1990. **Distinguishing error from chaos in ecological time series**. Philosophical Transactions of the Royal Society of London B. 330: 235-251.

analysis, time series, long-term ecological monitoring, natural variability.

1207. Sullivan, K. M.; Chiappone, M. 1993. **Hierarchial methods and sampling design for conservation monitoring of tropical marine hard bottom communities**. Aquatic Conservation. 3: 169-187.

Monitoring methods were tested in a 4-year study at 2 sites to determine which would detect changes in spatial patterning and benthic diversity and allow assessment of possible effects of low-level, chronic, anthropogenic stressors. Specific sites were identified and mapped using 1:6000 scale aerial photographs. Photos were also used to locate the annually placed sampling transects to capture the maximum spatial heterogeneity. Parallel 25m transects, consisting of 25 contiguous $1m^2$ quadrats, were established annually at each site. Each quadrat was scored for cover by visual estimation. In addition, belt transects of twenty-five $1m^2$ quadrats were established in which the density of individuals or colonies were counted and the size of individuals or colonies measured. These data were analyzed at the taxa level and at the species level. Species checklists were also prepared for each site. Visual cover estimation was the most rapid, but was least sensitive to change. Species lists were compared using the Jaccard coefficient for between years and sites; changes in terms of loss or gain of species, and changes in species diversity could be monitored by this approach. Belt transects were the most expensive in terms of time, but provided information on changes in species patterns, density and size class distribution. Species level sampling was more time consuming and provided no additional information over taxa level sampling. The authors recommend that: 1) attention to Type II errors is more important in a conservation setting than Type I errors; 2) multiple sites increase the power of interpretation; and 3) a hierarchical approach is preferred, in which the less sensitive methods are applied at a large number of sites.

general examples, objectives, pattern, community composition, community structure, ocular estimation, species lists, density, cover, aerial photography, Type I and Type II errors, power, analysis, design, community-level, field techniques, cover, density.

1208. Sutter, R. D. 1986. **Monitoring rare plant species and natural areas--ensuring the protection of our investment**. Natural Areas Journal. 6: 3-5.

rare species, objectives, monitoring overviews, special sites, natural areas.

1209. Swaine, M. D.; Greig-Smith, P. 1980. **An application of principle components analysis to vegetation change in permanent plots**. Journal of Ecology. 68: 33-41.

Spatial and temporal trends may be confused in ordinations of successional gradients. This paper illustrates a method to analyze data from permanent plots (a three-dimensional matrix of stand x species x time) using a data set of 3 grazing treatments, each with 4 replicates, at 9 sites, evaluated in permanent plots over a 12-year period. To analyze these data, the 4 replicates were summed to reduce data volume. From the species x time matrix for a single stand, a matrix of species cross-products can be calculated. The sum of the matrices can be analyzed by principle component analysis (PCA), and reflects within-stand variation. Graphing of the stand score along the first (and possibly second) PCA axis against time provides a visual assessment of differences in compositional patterns over time between the 3 treatments at each site. A major limitation of the method, in addition to the ones commonly associated with PCA, is that pairs of species may not show consistent correlation in their change with time (a pair may have positive correlation in one environment and negative in another). When summed, such opposite correlations will tend to zero in the matrix used for PCA.

analysis, community-level, permanent plots, community composition, community change, multivariate analysis, ordination.

1210. Swanson, F. J.; Sparks, R. E. 1990. **Long-term ecological research and the invisible place**. BioScience. 40(7): 502-508.

long-term ecological monitoring, ecological monitoring programs.

1211. Swartzman, G. L. 1987. **Long-term research in ecological models for environmental management**. In: Draggan, S.; Cohrssen, J. J.; Morrison, R. E., eds. Environmental monitoring, assessment, and management: the agenda for long-term research and development. New York, NY: Praeger Publishers: 63-88.

Models of ecosystem dynamics are increasing in number (perhaps currently more than 5000) and use in the assessment of impacts from human activities. These models serve important functions: improve understanding of ecosystems, identify important knowledge gaps, summarize the present understanding of the system, and focus and communicate information in a concise manner. Large-scale impacts are often addressed by models because there is no other way to assess them. The problem is that few of the parameters (often <25%) within the model can be estimated by actual data. With smaller-scale impacts, more of the parameters can be estimated, but models often suffer from unrealistic results due to heterogeneity and variability of parameters. Management models, such as tree growth models, may be fairly accurate in the short term, but are less effective when applied to problems like forest succession. To be effective, models must be validated by long-term monitoring such as the Long Term Ecological Reasearch (LETR) sites in the U.S.

monitoring examples, natural variability, ecological models, long-term ecological monitoring, predicting change.

1212. Sykes, J. M.; Horrill, A. D.; Mountford, M. D. 1983. **Use of visual cover assessments as quantitative estimators of some British woodland taxa**. Journal of Ecology. 71: 437-450.

Ten observers estimated cover of woodland understory species to the nearest 5% at 8 sites in a 14x14m plot, a 7x7m plot, and a 2x2m plot. Differences between observers was highest for the largest quadrat, up to 88% of the mean (for all observers). Differences in the smallest plot ranged from 17% to 39%. For all quadrat sizes combined, the 90% confidence interval of an individual observer was between 10% to 20% cover. By using the average for 4 individuals, this confidence interval was halved. Observers tended to consistently over or underestimate cover, but some observers made both over and under estimations. Variability was highest in the central region of the cover scale (near 50%) and lowest at the upper and lower ends.

field techniques, cover, canopy cover, ocular estimation, observer variability, deciduous forest, woodland.

1213. Synnott, T. J. 1979. **A manual of permanent plot procedures for tropical rain forest**. Tropical For. Pap. 14. Oxford, England: University of Oxford, Commonwealth Forestry Institute. 67 p.

monitoring examples, field techniques, permanent plots, forest, tree.

1214. Tadmor, N. H.; Brieghtt, A.; Noy-Meir, I.; Benjamin, R. W.; Eyel, E. 1975. **An evaluation of the calibrated weight-estimate for measuring production in annual vegetation**. Journal of Range Management. 28: 65-69.

field techniques, production, weight estimate, annuals, herbaceous species.

1215. Taha, F. K.; Fisser, H. G.; Ries, R. E. 1983. **A modified 100-point frame for vegetation inventory**. Journal of Range Management. 36: 124-125.

The suggested frame is a base 30x60cm, with five positions for placement of a perpendicular frame that holds 20 moveable pins.

field techniques, cover, canopy cover, point intercept, point frames, tools.

1216. Tainton, N. M.; Edwards, P. J.; Mentis, M. T. 1980. **A revised method for assessingveld condition**. Proceedings of the Grassland Society of Southern Africa. 15: 37-52.

grassland, field techniques, general examples, inventory.

1217. Tanke, W. C.; Bonham, C. D. 1985. **Use of power curves to monitor range trend**. Journal of Range Management. 38: 428-431.

This paper provides a good description of the implications of Type I and Type II errors in terms of a common range management issue: range trend. In monitoring range trend, the null hypothesis is that trend is static. A Type I error would be the rejection of this hypothesis when it is actually true. If the manager erroneously believes the trend is up, and increases stocking, there could be a decrease in condition and forage production. If the manager erroneously believes the trend down, and stocking is decreased, there are economic implications to the ranching operation. A Type II error would be to falsely assume the null hypothesis is correct, that range trend is static. If trend is actually down, continued stocking could cause further decrease in range condition; if actually up, failure to measure that upward trend could result in loss of potential increases in stocking for the ranch operation. The implications of both types of error are similar, thus error rates should be set at similar levels. In actuality, most monitoring controls for the Type I error rate (often setting it at the 5% level) while Type II error rate is rarely considered. The authors demonstrate the use of power curves that describe the power (power = 1.00 - Type II error) of the test to detect a given level of change at a given Type I error rate. Power curves allow easy visualization of the trade-offs between Type I and II error rates, and the adequacy of the current monitoring. Power curves can also be constructed for different sample sizes, allowing managers to assess the information value of increasing sample size.

design, rangeland, detecting change, power, precision, Type I and Type II errors, analysis.

1218. Tanner, G. W.; Drummond, M. E. 1985. **Technical notes -- a floating quadrat**. Journal of Range Management. 38(3): 287.

This brief technical note describes construction of a frame for sampling emergent wetland vegetation. The frame made of 0.5in PVC pipe floats when placed on water surfaces. This low-cost frame is compact and portable, and may be utilized for terrestrial vegetation as well.

field techniques, tools, wetland.

1219. Tate, M. W.; Hyer, L. A. 1973. **Inaccuracy of the chi-square test of goodness of fit when expected frequencies are small**. Journal of The American Statistical Association. 68: 836-841.

analysis, nonparametric statistics, sample size.

1220. Tausch, R. J.; Wigand, P. E.; Burkhardt, J. W. 1993. **Viewpoint: plant community thresholds, multiple steady states and multiple successional pathways: legacy of the Quaternary?** Journal of Range Management. 46(5): 439-447.

This paper provides a valuable discussion on the long-term (millions of years) perspective of climate cycles and associated vegetation changes. Reconstruction of vegetation history through the paleo record in the Great Basin shows that an important contributor to current vegetation dynamics was the climatic variation of the Quaternary. The authors assert that changes in plant communities are unique at each location, difficult to define, and that plant species respond individually to climate changes. The authors challenge that many long-standing ecological principles and concepts and associated ecosystem paradigms require revision based on this new knowledge. They suggest that concepts of thresholds, multiple steady states, and multiple successional pathways are useful in understanding the dynamic interrelationships of vegetation and environmental change.

environmental monitoring programs, predicting change, community composition, rangeland, woodland, succession, natural variability, community change, community-level, global change monitoring.

1221. Taylor, B. L.; Dizon, A. E. 1996. **The need to estimate power to link genetics and demography for conservation**. Conservation Biology. 10: 661-664.

power, demographic techniques, rare species.

1222. Taylor, B. L.; Gerrodette, T. 1993. **The uses of statistical power in conservation biology: the vaquita and northern spotted owl**. Conservation Biology. 7: 489-499.

In conservation biology, the consequences of accepting a false null hypothesis (that there has been no change in the population) can be serious because a small population size leaves the species vulnerable to extinction. In this paper's first example, power analysis suggests that even the most intensive survey design for the vaquita will detect an annual decline of only 18% or more, or 86% decline over the ten-year monitoring period (given an assumed population size of 300, the known coefficient of variation, and error rates of $\beta=\alpha=.05$). Smaller rates of decline will not be detected. In the second example, power analysis was completed on a demographic study of the northern spotted owl by generating through simulation a distribution for the null hypothesis (no change) and for a 4% decline. This procedure suggests that power is only 0.64; in other words, the null hypothesis of no change would be rejected in only 64% of the estimates even though there was actually a change of 4%. An alternate approach that considers a confidence interval around the observed trend, however, gives a power of only 0.08 (a real downward trend would be missed 92% of the time). Finally, power analysis was used to determine the more effective monitoring method: a demographic approach or a population survey (counts) approach. The authors found that for small populations, the demographic approach is always the more powerful, but as populations increase a trade-off point is reached where the survey method becomes more powerful.

detecting change, power, precision, experimental design, sampling design, Type I and Type II errors, design, demographic techniques.

1223. Taylor, C. H.; Loftis, J. C. 1989. **Testing for trend in lake and groundwater quality time series**. Water Resources Bulletin. 25: 715-726.

analysis, time series, trend analysis.

1224. Taylor, C. E.; Spurr, R. E. 1973. **Aerial photographs in the national archives**. Special List Number 25. Washington, DC: National Archives and Records Service, General Services Administration. 106 p.

remote sensing, aerial photography.

1225. Tazik, D. J.; Warren, S. D.; Diersing, V. E.; Shaw, R. B.; Brozka, R. J.; Bagley, C. F.; Whitworth, W. R. 1992. **U.S. Army land condition-trend analysis (LCTA) plot inventory field methods**. Tech. Rep. N-92/03. Champaign, IL: U.S. Department of the Army, Construction Engineering Research Laboratory. 62 p.

monitoring examples, ecological monitoring programs, field techniques.

1226. Tedonkeng Pamo, E.; Pieper, R. D.; Beck, R. F. 1991. **Range condition analysis: comparison of two methods in southern New Mexico desert grasslands**. Journal of Range Management. 44: 374-378.

rangeland, grassland, inventory, community composition, community-level, field techniques.

1227. Telfer, E. S. 1969. **Weight-diameter relationships for twenty-two woody plant species**. Canadian Journal of Botany. 47: 1851-1855.

field techniques, production, shrub.

1228. Ter Braak, C. J. F.; Wiertz, J. 1994. **On the statistical analysis of vegetation change: a wetland affected by water extraction and soil acidification**. Journal of Vegetation Science. 5: 361-372.

Change measured in 20 permanent plots in a wetland is used to demonstrate statistical analysis of vegetation change where data on the present environmental conditions are limited and on the past, non-existent. Previously determined wetland indicator values for each species were used to interpret change in terms of groundwater table and acidity. Species composition was described in each of twenty 20x20m blocks in a 4x5 grid (80x100m) as absent, rare, frequent, and abundant. Significance of changes for each species was tested using a Wilcoxon signed rank test. Mean indicator values (for all species in each plot) and species richness were compared similarly. Initial multivariate analysis with Detrended Correspondence Analysis (DCA) yielded axes lengths of less than two standard deviations, thus redundancy analysis was used. Significance was tested by a Monte Carlo simulation.

analysis, field techniques, frequency, cover, community composition, community change, multivariate analysis, species richness, wetland, cover classes, ocular estimation, nonparametric statistics, ordination, detecting change, biological significance.

1229. The Institute of Ecology. 1977. **Experimental ecological reserves: a proposed national network**. Washington, DC: National Science Foundation. 43 p.

Stimulated by the International Biological Program in the late 1960s and early 1970s, a network of Experimental Ecological Reserves is proposed. These reserves are to be in natural ecosystems and of large enough size for portions to be experimentally altered.

monitoring examples, integrated monitoring, ecological monitoring programs, reference areas, special sites.

1230. Thomas, J. M.; McKenzie, D. H.; Eberhardt, L. L. 1981. **Some limitations of biological monitoring**. Environment International. 5: 3-10.

Four purposes of biological monitoring are recognized: 1) assess normal population fluctuations; 2) meet resource management needs; 3) assure compliance with regulations (these three considered "baseline monitoring"); and 4) assign cause for observed changes or pollutant levels in biota (termed here "analytical monitoring"). Baseline monitoring data can be difficult to interpret because of the effects of compensatory responses (adjustment to stress causes non-linear and threshold responses) and indirect causes. Monitoring to detect causes is often ineffective because of infrequent sampling, little pre-stress data or baseline information on natural fluctuations, lack of control mechanisms, and inconsistent methodologies throughout the study. The most common analysis techniques for this type of data are often misapplied. Regression analysis may show spurious correlations of biotic change with levels of stress (pollutant). Analysis of variance models are often complicated with fixed and nested effects and an unbalanced design (unequal numbers of observations in each treatment). Paired stations (control with treatment) can be used to generate relational ratios of pre- and post-treatment conditions, but there are often logistical problems in identifying paired stations.

monitoring overviews, natural variability, design, baseline monitoring, detecting change, sampling design, monitoring definitions, analysis, statistical interpretation, objectives.

1231. Thomas, L. 1996. **Monitoring long-term population change: why are there so many analysis methods?** Ecology. 77: 49-58.

objectives, rare species, long-term ecological monitoring.

1232. Thompson, K.; Hillier, S. H.; Grime, J. P.; Bossard, C. C.; Band, S. R. 1996. **A functional analysis of a limestone grassland community**. Journal of Vegetation Science. 7: 371-380.

functional groups, grassland, community change, community-level.

1233. Thompson, S. K. 1990. **Adaptive cluster sampling**. Journal of American Statistical Association. 85: 1050-1058.

Many rare biological phenomena such as rare plants, are distributed in space in clumps. Because of this distribution, most sampling units distributed in space by familiar sampling designs (such as simple random) will not contain the item of interest. Adaptive cluster sampling is a design in which an initial set of sampling units is selected by some probability sampling procedure (such as a random sample). If one of these units contains the item of interest, additional adjacent units are selected and sampled. This allows the sampling intensity to vary depending on the occurrence of the item of interest, thus many more sampling units will contain the rare item. Normal methods of estimating the mean and variance of such a sample are not appropriate, because the sample is obviously biased in favor of the rare event. In this article several estimators are presented that are not biased by designs, and can be used for a sample resulting from adaptive cluster sampling. The included examples demonstrate that for rare clustered populations this method is more efficient than conventional sampling strategies.

analysis, cluster sampling, precision, random sampling, sampling design.

1234. Thompson, S. K. 1991. **Adaptive cluster sampling: designs with primary and secondary units**. Biometrics. 47: 1103-1115.

Sampling designs such as simple random or systematic are of minimal efficiency in sampling organisms that are aggregated because most of the sampling units will not contain the item of interest. Adaptive cluster sampling is a design in which an initial set of sampling units is selected by some probability sampling procedure (such as a random sample). If one of these units contains the item of interest, addition adjacent units are selected and sampled. In designs

with primary and secondary units, the initial units are of a different size and/or shape than the additional units (secondary units). Because the sample is biased in favor of capturing the rare event, usual methods of estimating the mean and variance are inappropriate. Formulas for estimating mean and variance for a sample resulting from adaptive cluster sampling are presented. The included examples demonstrate that for rare clustered populations, such as rare plant populations, adaptive cluster sampling is is usually more efficient than conventional sampling strategies.

design, analysis, cluster sampling, precision, random sampling, sampling design.

1235. Thompson, S. K. 1992. **Sampling.** New York, NY: John Wiley and Sons. 368 p.

design, analysis, statistics overview, sampling design.

1236. Thompson, S. K. 1991. **Stratified adaptive cluster sampling.** Biometrika. 78: 389-397.

design, analysis, cluster sampling, sampling design.

1237. Tiedemann, A. R.; Klock, G. O. 1977. **Meeks Table Research Natural Area: reference sampling and habitat classification**. Res. Pap. PNW-223. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

special sites, general examples, natural areas, community classification, baseline monitoring.

1238. Tilman, D.; Wedin, D. 1991. **Oscillations and chaos in the dynamics of a perennial grass**. Nature. 353: 653-655.

objectives, natural variability, general examples.

1239. Todd, J. E. 1982. **Recording changes: field guide to establishing and maintaining permanent camera points**. R6-10-095-1982. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

field techniques, photopoints.

1240. Toft, C. A.; Shea, P. J. 1983. **Detecting community-wide patterns: estimating power strengthens statistical inference**. American Naturalist. 122: 618-625.

When a null model is not rejected, it is concluded that certain patterns are not statistically demonstrated to exist. Equally interesting, but rarely considered, is how well the test determines whether the null hypothesis is false, i.e., the power of the test to detect a real difference. The chosen alpha level (Type I error rate), usually p=0.05, will affect the power. An alpha level of 0.05, and a corresponding power of 0.85 implies that a Type I error is three times more important than aType II error. Power is also affected by sample size (the larger the sample, the more reliable the estimate and the smaller the probability of both types of errors) and the effect size (the larger the difference the more likely that it will be detected). The authors suggest that in investigations of causes of community patterns, power analysis can provide a measure of the sensitivity of null hypothesis tests.

design, analysis, power, precision, detecting change, community change, Type I and Type II errors.

1241. Travis, J.; Sutter, R. 1986. **Experimental designs and statistical methods for demographic studies of rare plants**. Natural Areas Journal. 6(3): 4-12.

demographic techniques, rare species.

1242. Treshow, M.; Allan, J. 1985. **Uncertainties associated with the assessment of vegetation.** Environmental Management. 9(6): 471-478.

sampling design, design, field techniques, observer variability.

1243. Treskonova, M. 1991. **Changes in the structure of tall tussock grasslands and infestation species of *Hieracium* in the Mackenzie Country, New Zealand.** New Zealand Journal of Ecology. 15: 65-78.

grassland, community change, community structure, community composition, community-level, exotics.

1244. Tueller, P. T. 1988. **Vegetation science applications for rangeland analysis and management**. Boston: Kluwer Academic Publishers. 642 p.

vegetation sampling overview, rangeland, monitoring and management.

1245. Tueller, P. T.; Lorain, G.; Kipping, K.; Wilkie, C. 1972. **Methods for measuring vegetation changes on Nevada rangelands.** Tech. Rep. T16. Reno, NV: University of Nevada Agricultural Experiment Station. 55 p.

field techniques, vegetation sampling overview, community change, rangeland, community-level, monitoring overviews, field techniques, density, cover, frequency.

1246. Tueller, P. T.; Platou, K. A. 1991. **A plant succession gradient in a big sagebrush/grass ecosystem.** Vegetatio. 94: 57-68.

community change, community structure, succession, community-level, shrubland, shrub grassland, grassland, rangeland.

1247. Tukey, J. W. 1977. **Exploratory data analysis**. Reading, MA: Addison-Wesley. 688 p.

Includes a large number of graphical analysis techniques that can be used for initial evaluation and presentation of data.

analysis, graphical analysis, statistics overview.

1248. Turchin, P.; Taylor, A. D. 1992. **Complex dynamics in ecological time series.** Ecology. 73: 289-305.

analysis, time series, covariance, long-term ecological monitoring.

1249. Turner, D. L. 1990. **Estimates without measures of precision are unacceptable**. Monitoring and evaluation of fish, sensitive plants, and wildlife: a national workshop for Forest Plan implementation; Park City, UT; 1990 June 5-7. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: [irregular pagination].

This paper provides an excellent introduction to concepts of sampling, the accuracy and precision of a sample, and the critical nature of confidence intervals in any estimation of a population parameter. The paper is written for resource managers contemplating a monitoring program.

design, analysis, monitoring and management, sampling design, confidence intervals, ecological monitoring programs, statistics overview, biological significance, monitoring overviews, statistical interpretation.

1250. Turner, D. P.; Koerper, G.; Guckinski, H.; Peterson, C. 1993. **Monitoring global change: comparison of forest cover estimates using remote-sensing and inventory approaches.** Environmental Monitoring and Assessment. 26: 295-305.

vegetation mapping, tree, monitoring examples, global change monitoring, forest, remote sensing, inventory.

1251. Turner, M. G. 1990. **Spatial and temporal analysis of landscape patterns**. Landscape Ecology. 4: 21-30.

landscape-level, pattern, landscape change, scale.

1252. Turner, M. G.; Gardner, R. H. 1991. **Quantitative methods in landscape ecology**. New York, NY: Springer-Verlag. 536 p.

landscape-level, analysis, landscape change, pattern, large-scale monitoring.

1253. Turner, M. G.; Ruscher, C. L. 1988. **Changes in landscape patterns in Georgia, USA**. Landscape Ecology. 1: 241-251.

landscape change, landscape-level, pattern, remote sensing, general examples.

1254. Turner, R. M. 1990. **Long-term vegetation change at a fully protected Sonoran desert site**. Ecology. 71: 464-477.

The author reports on long-term vegetation studies on a Sonoran desert site fully protected from livestock grazing and other human manipulations. The methods involve a combination of photographic techniques and vegetation mapping in permanent plots. Photopoints established in 1907 were re-photographed at irregular intervals through 1986. The photographs were utilized to monitor recruitment and mortality of dominant vegetation including saguaro, palo verde, creosote bush, mesquite, and brittle bush. Three non-replicated permanent plots, of varying sizes, were established to monitor population changes of saguaro and creosote bush. The author mentions that both density and canopy cover measurements were taken, but does not explain how the latter were measured. The paper reports on changes in total number of individuals. From these data the author documents changes in dominant species population structure over time, and correlates these changes with broad climatic conditions. These methods provide a useful way of documenting individual species patterns over time.

field techniques, density, cover, monitoring examples, permanent plots, long-term ecological monitoring, photopoints, desert, charting.

1255. Tyrrell, L. E.; Funk, D. T.; Scott, C. T.; Smith, M.; Parker, L.; DeMeo, T. E. 1994. **Research natural area monitoring field guide**. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Region 9. 136 p.

This draft publication describes a monitoring methodology for use in research natural areas. The method was developed within the following constraints: 1) useable on forest, grassland, wetland, and alpine systems; 2) statistically defensible plot design; 3) adaptable to a variety of management situations; 4) not limited to vegetation monitoring. The publication provides complete detailed directions for the proposed methods or references to other publications where directions are given. The first chapters describe the collection of site attribute data such as 1) physical characteristics of climate and water chemistry; 2) cultural characteristics such as site history and human disturbance patterns; and 3) biotic attributes surveyed by four techniques (gap, floristic, faunal, and plot surveys). The next chapter describes the establishment of plots and sampling of vegetation within plots. Sampling is done by Ecological Land Type (ELT). Plots are circular, 0.125ha in size, arranged in a regular grid, and joined by gap survey transects that extend the length of the ELT. In each plot tree data are recorded and in smaller nested plots data are recorded on the density of shrubs, tree seedlings, ground cover, and vertical structure. Information is included on use of a data recorder for collecting field data, but no directions are given for analysis or summary of collected data.

ecological monitoring programs, inventory, long-term ecological monitoring, natural areas, natural areas, community change, density, canopy cover, DBH, crown diameter, heights, field techniques, monitoring examples, inventory, cover, permanent plots, special sites.

1256. Umbanhowar, C. E. 1992. **Early patterns of revegetation of artificial earthen mounds in a northern mixed prairie**. Canadian Journal of Botany. 70: 145-150.

In this study the revegetation of disturbance gaps was monitored on artificially-created earthen mounds that mimicked natural mounds constructed by common prairie animals. Stem density of grasses and forbs was recorded on 9 growing season dates over a period of 2 years. During the first year, individual plants were marked with toothpicks, but the method failed because of trampling by bison. In the second year, censusing was completed using a 7.5dm grid with 20 equal sectors arranged in 3 concentric rings. Off-mound vegetation was sampled with the same grid. Analysis included tests for differences in density by mound

position and prairie type, compositional comparisons using Bray-Curtis ordination and multi-response permutation procedures, and on- and off-mound differences using paired t-tests. This paper provides an example of monitoring small-scale disturbances in grassland communities.

community-level, monitoring examples, special sites, field techniques, natural areas, disturbance, community composition, community structure, species diversity, grassland, density, demographic techniques, scale, multivariate analysis.

1257. Underwood, A. J. 1991. **Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations**. Australian Journal of Marine and Freshwater Research. 42: 569-587.

design, aquatic, BACI, sampling design, detecting change, power.

1258. Underwood, A. J. 1992. **Beyond BACI: the detection of environmental impacts on populations in the real, but variable world.** Journal of Experimental Marine Biology and Ecology. 161: 145-178.

design, detecting change, BACI, power, sampling design.

1259. Underwood, A. J. 1991. **Biological monitoring for human impact: how little it can achieve**. In: Hyne, R. V., ed. Proceedings of the 29th Congress of the Australian Society of Limnology; Jabiru, Australia. Canberra, Australia: Australian Government Publishing Service: 105-123.

detecting change, monitoring and management, design.

1260. Underwood, A. J. 1993. **The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world**. Australian Journal of Ecology. 18: 99-116.

design, sampling design, BACI, disturbance, detecting change.

1261. Underwood, A. J. 1994. **On beyond BACI: sampling designs that might reliably detect environmental disturbances**. Ecological Applications. 4(1): 3-15.

design, BACI, sampling design, experimental design, detecting change.

1262. Underwood, A. J. 1990. **Pilot studies for designs of surveys of human disturbance of intertidal habitats in New South Wales**. Australian Journal of Marine and Freshwater Research. 41: 165-173.

design, pilot study, aquatic, detecting change.

1263. Uresk, D. W. 1990. **Using multivariate techniques to quantitatively estimate ecological stages in a mixed grass prairie**. Journal of Range Management. 43(4): 282-285.

multivariate analysis, grassland, community classification, rangeland, community composition, succession, ecological models.

1264. Ursic, S. J.; McClurkin, D. C. 1959. **Small plots for measuring vegetation composition and cover**. Techniques and methods of measuring understory vegetation. Tifton, GA: U.S. Department of Agriculture, Forest Service: 70-78.

Rectangular plots were found generally more efficient than square or circular plots of the same size. The authors suggest that this advantage exists because rectangular plots encompass a better representation of local variation in the vegetation.

design, plot dimensions, sampling design, cover, herbaceous species, community-level, community composition.

1265. U.S. Department of Interior, Bureau of Land Management. 1985. **Rangeland monitoring trend studies**. Tech. Ref. 4400-4. Denver, CO: U.S. Department of Interior, Bureau of Land Management, Denver Service Center. 130 p.

Several standardized monitoring methods for measuring trend on rangelands are presented. Each is completely described in terms of equipment needed, plot design, and data taken. Data sheets are included. Methods covered are: photoplots, community structure analysis, Daubenmire cover plots, pace frequency, quadrat frequency, nested frequency, line intercept, and step-point transect.

field techniques, cover, community composition, rangeland, canopy cover, cover classes, line intercept, ocular estimation, point intercept, photoplots, nested frequency, frequency.

1266. U.S. Department of Interior, Bureau of Land Management. 1992. **Rangeland inventory and monitoring supplemental studies**. Tech. Ref. 4400-5. Denver, CO: U.S. Department of Interior, Bureau of Land Management, Denver Service Center. 291 p.

This reference describes in detail all methods used by the Bureau of Land Management for range inventory and monitoring since formation of the Grazing Service. Included are methods used for range survey (reconnaissance method and square foot density method), trend studies (Parker three-step, Deming two-phase and trend score card), forage surveys (weight estimate and ocular estimate), the apparent trend method, and soil-vegetation inventory method (SVIM). The reference is useful for analysis and understanding of studies established in the 1940s through the early 1970s.

field techniques, community change, community-level, community composition, vegetation mapping, rangeland, density, cover, production.

1267. U.S. Department of Agriculture, Forest Service. 1992. **Forest Service resource inventories: an overview**. Washington, DC: U.S. Department of Agriculture, Forest Service, Forest Inventory, Economics, and Recreation Research. 39 p.

inventory, forest, general examples, agency guidance and policy.

1268. U.S. Department of Interior, National Park Service. 1990. **Shenandoah National Park, long-term ecological**

monitoring system. NPS/NRSHEN/NRTR-90/02. Denver, CO: U.S. Department of Interior, National Park Service.

This publication describes Phase I of a relatively new long-term ecological monitoring system (LTEMS) developed for the Shenandoah National Park. The LTEMS consists of 3 modules--a forest component, an aquatic component, and a gypsy moth component. The park was particularly concerned about future impacts of the alien gypsy moth on forested systems. The forest monitoring component consists of a series of permanent plots located systematically to represent a range of ecological land units within the park. The purpose of monitoring these plots over time is to evaluate changes in forest composition, structure, regeneration, and growth, relative to natural and anthropogenic disturbances. A 24mx24m macroplot is used for tree measurements. Three 6mx6m plots are located within the macroplot to measure shrubs. Each shrub plot contains two 1mx1m subplots to measure regeneration. Specific instructions and forms for each component are detailed in 3 separate user manuals. The final section of this publication is a user manual for data management and analysis for the 3 LTEMS components.

monitoring examples, ecological monitoring programs, national parks, long-term ecological monitoring, permanent plots, forest, aquatic, disturbance, data management, analysis, community change.

1269. U.S. Department of Interior, National Park Service. 1992. **Western Region fire monitoring handbook**. San Francisco, CA: Western Region Prescribed and Natural Fire Monitoring Task Force. 134 p.

monitoring examples, agency plans, national parks, general book on monitoring.

1270. Usher, M. B. 1988. **Biological invasions of nature reserves: a search for generalizations**. Biological Conservation. 44: 119-135.

This paper is a summary paper for a special issue of Biological Conservation on invasive species. The author uses 4 other papers in the issue that each describe invasions in broadly defined habitat types as a basis for generalizations, 24 reserves in all. Invasive vascular plant species averaged about 30% for the flora of island reserves, but only 5% to 12% for arid, dry woodlands and Mediterranean sites. Nearly 18% of the fauna of islands were invasive introduced species, compared to less than 1% for dry woodlands. Reservese used for tourism had higher levels of invasive species than those rarely visited. In nearly all reserves, some form of control was being attempted. Invasive species that threatened endemic species, and those that created an observable landscape-level impact were the highest priority for control.

special sites, community-level, landscape-level, exotics, national parks, natural areas, vegetation treatments, community composition, rare species.

1271. Vales, D. J.; Bunnell, F. L. 18. **Comparison of methods for estimating forest overstory cover. I. Observer effects**. Canadian Journal of Forest Research. (606-609)

field techniques, technique comparison, cover, canopy cover, tree, observer variability.

1272. van Andel, J.; Bakker, J. P.; Grootjans, A. P. 1993. **Mechanisms of vegetation succession: a review of concepts and perspectives**. Acta Botanica Neerlandica. 42: 413-433.

succession, community-level, community change, predicting change, ecological models.

1273. Van Cleve, K.; Martin, S. 1991. **Long-term ecological research in the United States: a network of research sites. 6th ed.** Seattle, WA: University of Washington, College of Forest Resources, Long-term Ecological Research Network Office. 178 p.

This publication serves as a guidebook to the 18 sites included within The National Science Foundation's Long-Term Ecological Research (LTER) Program in the United States. For each LTER site in the network, detailed descriptions accompanied by photographs and graphics describe the research setting, site characteristics, research program status, and anticipated future research directions. This publication provides a useful summary of state-of-the-art long-term ecosystem monitoring. The future directions section is a good source of ideas for anyone developing an ecological monitoring program.

monitoring examples, ecosystem, long-term ecological monitoring, permanent plots, landscape-level.

1274. van der Valk, A. G.; Davis, C. B. 1994. **Assessing the impacts of an increase in water level on wetland vegetation**. Ecological Applications. 4: 525-534.

Ten 6 to 8ha cells in a Manitoba marsh, each isolated by dikes with a pumping system to control water level, were used to test the effects of water level changes and to compare the sensitivity of different measurement methods to change. Flooding treatments of 30cm or 60cm were randomly assigned to 3 cells each; 4 cells were used as controls. Changes were monitored over 5 years by 3 methods: 1) Vegetation maps were prepared from low-level infrared aerial photographs and compared for the amount of open water, sparse vegetation, litter, and vegetation types. 2) Ten permanent 2x2m quadrats were established using a restricted random design. Each was subdivided into 4 triangular subplots, 2 of which were measured and 2 of which allowed access. Shoots of emergent species were counted and cover estimated. Indicators of change used were species richness (number of species per subplot), total shoot density, cover, Shannon's diversity index, and Simpson's index. 3) The Bray-Curtis similarity index was used to measure changes in diversity within a cell over the 5 years. The following showed statistically significant treatment effects: the percent of cell covered by open water, the number of vegetation types, the number of multispecies

vegetation types, mean species richness, shoot density, and Shannon's index. Similarity indices gave mixed results, showing a year effect, but not a treatment effect. The authors concluded that vegetation attributes such as total shoot density and species richness from permanent quadrats were the best indicators, robust enough to deal with heterogeneity, succession, and treatment.

community-level, disturbance, vegetation treatments, community composition, cover typing, habitat mapping, species richness, species diversity, vegetation mapping, wetland, field techniques, density, cover, ocular estimation, diversity indices, detecting change, experimental design, technique comparison, community change, aerial photography.

1275. van der Maarel, E. 1980. **Fluctuation in a coastal dune grassland due to fluctuations in rainfall: experimental evidence.** Vegetatio. 47: 259-265.

Vegetation changes in forty 2mx2m plots between 1963 and 1970 suggested progressive succession from open to more closed grassland communities dominated by tall grasses. Very dry summers occurred between 1970 and 1977, and the tall grasses largely disappeared from the community, forcing the abandonment of the model of directional change. To test the hypothesis of climate driven change, 5 blocks of 3 quadrats each were established in the study area. Cover of each species was ocularly estimated using the Braun-Blanquet scale. Within each block, 1 quadrat was given more precipitation than average through watering and 1 was given less by interception of natural precipitation with a plastic cover. One quadrat served as a control. Categorical responses ranging from strong increase to strong decrease are presented for all major species encountered, but there is no significance testing of the differences between treatments and controls.

community change, predicting change, succession, ocular estimation, cover classes, community-level, field techniques.

1276. van der Maarel, E. 1978. **On the treatment of succession data.** Phytocoenosis. 7: 257-258.

community-level, community change, succession, multivariate analysis, analysis.

1277. van der Maarel, E. 1988. **Vegetation dynamics: patterns in time and space.** Vegetatio. 77: 7-19.

community-level, community change, pattern, natural variability, succession, detecting change.

1278. Van Dyne, G. M. 1960. **A procedure for rapid collection, processing and analysis of line intercept data.** Journal of Range Management. 13: 247-251.

field techniques, cover, line intercept.

1279. Van Horn, M.; Van Horn, K. 1996. **Quantitative photomonitoring for restoration projects.** Restoration and Management Notes. 14: 30-34.

field techniques, photopoints, photoplots.

1280. Van Hulst, R. 1978. **On the dynamics of vegetation: patterns of environmental and vegetational change.** Vegetatio. 38: 65-75.

community-level, natural variability, succession, community change.

1281. Van Riper III, C., Stohlgren, T. J., Veirs Jr., S. D., Hillyer, S. C., eds. 1990. **Examples of resource inventory and monitoring in national parks in California--proceeding of third biennial conference on research in California's national parks**; 1990 September 13-15; University of California. Davis, CA: U.S. Department of Interior, National Park Service. 268 p.

inventory, monitoring examples, special sites, national parks.

1282. vanBelle, G.; Hughes, J. P. 1984. **Nonparametric tests for trend in water quality.** Water Resources Research. 20: 127-136.

analysis, trend analysis, nonparametric statistics.

1283. Vanclay, J. K. 1992. **Permanent plots for multiple objectives: defining goals and resolving conflicts.** In: Lund, H. G.; Paivinen, R.; Thammincha, S., eds. Remote sensing and permanent plot techniques for world forest monitoring: Proceedings of the IUFRO S4.O2.05 Wacharakitti International Workshop; 1992 January 13-17; Pattaya, Thailand. [Place of publication unknown]: International Union of Forest Research Organizations: 157-163.

The author provides a good discussion designing meaningful monitoring programs utilizing permanent plots. The first and most important step is to clearly define monitoring objectives and information needs. Permanent plots are more costly than temporary plots and require a commitment and plan for remeasurement. Permanent plots are generally used for detecting change. Due to the potential for high measurement errors relative to rate of change, it is important that protocols be flexible and robust. It is best to focus on variables which may be quantitatively measured rather than estimated. The author discusses the pros and cons of increasing efficiency by utilizing plots for several purposes. The next step in developing a monitoring plan is to determine the optimal design and placement? The author provides a table (in the form of a binary key) to assist in selection of a sampling design. This table incorporates consideration of information needs and available resources. The author outlines several basic considerations in selecting and designing measurment protocols for site variables, tree and other vegetation measurements, and plot documentation. The paper concludes with descriptions of different types of vegetation monitoring projects.

ecological monitoring programs, permanent plots, monitoring examples, field techniques, tree, herbaceous species, monitoring overviews.

1284. VanDyne, G. M. 1965. **A further note of random locations for sample units in circular plots**. Journal of Range Management. 18: 150-151.
field techniques, random sampling, plot selection.

1285. VanDyne, G. M. 1960. **A method for random location of sample units in range investigations**. Journal of Range Management. 13: 152-153.
To locate random sampling units from a central location while ensuring plots do not cluster near the center, a circular sampling area can be divided into concentric rings of equal area. In this example, these were divided into 10 areas of equal size by the use of diameter lines set at 36ft intervals. Each intersection of a concentric ring and a diameter was considered a potential sampling point, and the sample was chosen randomly from these.
field techniques, plot selection, random sampling.

1286. VanDyne, G. M.; Vogel, W. G.; Fisser, H. G. 1963. **Influence of small plot size and shape on range herbage production estimates**. Ecology. 44: 746-759.
Plots of varying sizes and shapes for estimating herbage production in a bunchgrass/shrub community were compared. At one site, 7 plot shapes with areas of either 1 or $2ft^2$ were used to measure total herbage. At a second site, 3 different rectangular plots, 1ft wide and varying in length from 2 to 6ft were used to measure production by life form. The number of plots and the total square feet to be clipped in order to estimate production within 10% of the mean, with a 90% confidence, was calculated for each plot size. At the first site, production was most efficiently estimated in circular plots of $2ft^2$. At the second site, the most efficient plot design varied by life forms, with the longest plot most efficient for total production estimates, graminoids and shrubs, but the 1ftx4ft most efficient for forbs.
shrub grassland, precision, production, plot dimensions, sampling design, design.

1287. Vane-Wright, R. I.; Humphries, C. J.; Williams, P. H. 1991. **What to protect? -- systematics and the agony of choice**. Biological Conservation. 55: 235-254.
objectives, indicators.

1288. VanSickle, C. 1983. **Measuring resource change in a changing world.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 36-38.
The author asserts that the problem with using agency timber inventories for monitoring resource change is that inventory methodologies change and are not comparable. Definitions for nearly every attribute measured differ between inventories, even basic ones such as growing stock volume, merchantable species, and number of saw timber trees. While changing inventory definitions may improve the inventories and better reflect current knowledge and resource use, it makes it impossible to use the data for measuring change. A further problem is that many of the attributes are synthetic ones, with inventory crews combining several stand characteristics in the field, thus the basic data cannot even be reconstructed. The author recommends inventories be designed with standard fundamental attributes (number of trees by diameter and species, timber volume), actual measurements be recorded in the field rather than class or interval values, and benefits of any changes in inventory methodology be weighed against the loss of data compatibility.
tree, objectives, inventory, forest.

1289. Ver Hoef, J. M. 1996. **Parametric empirical Bayes methods for ecological applications**. Ecological Applications. 6(4): 1047-1055.
analysis, Bayesian statistics.

1290. Verbyla, D. L. 1995. **Satellite remote sensing of natural resources**. Boca Raton, FL: Lewis Publishers. 224 p.
This book provides a technical but lucid introduction to satellite remote sensing. The first chapter gives a good overview of satellite imagery and the systems currently available that are useful for natural resources management. Other chapters describe how data is recorded and images produced, the spectral relationship of various types of ground characters, radiometric and geometric correction for satellite imagery, and supervised and unsupervised pixel classification techniques. Each chapter includes problems, with worked solutions to half of them in an appendix. Each chapter also includes additional reading suggestions which provide good access to the recent literature on satellite remote sensing.
pattern, regional planning, GIS, Landsat, MSS, TM, AVHRR, remote sensing.

1291. Vestal, A. G.; Herrmans, M. F. 1945. **Size requirements for reference areas in mixed forests**. Ecology. 26: 122-134.
special sites, reference areas, permanent plots, forest.

1292. Vogelmann, J. E.; Rock, B. N. 1986. **Assessing forest decline in coniferous forests of Vermont using NS-001 Thematic Mapper simulator data**. International Journal of Remote Sensing. 7(10): 1303-1321.
remote sensing, forest, tree, large-scale monitoring, TM.

1293. Vogelmann, J. E.; Rock, B. N. 1986. **Assessing forest damage in high-elevation coniferous forests in Vermont and New Hampshire using Landsat Thematic Mapper data.** Remote Sensing of The Environment. 24: 227-246.
tree, forest, landscape-level, Landsat, TM, remote sensing.

1294. Vujakovic, P. 1987. **Monitoring extensive "buffer zones" in Africa: an application for satellite imagery**. Biological Conservation. 39: 195-208.

Buffer zones around wildlife preserves in Botswana and Zimbabwe are intended to serve as areas in which controlled exploitation of wildlife would occur. These areas buffer the preserve from more intense human land use, reduce the destruction of crops and livestock by wildlife, and provide corridors for movement. Monitoring these areas is a challenge because of their size and inaccessibility. Of primary interest in this study were increases in woody cover which would decrease available forage for wildlife and livestock within the buffer zones. Reflectance values for 49 study areas were calculated from Landsat multispectral sensor (MSS) data. These data were collected when herbaceous material was mostly dried or grazed, but woody canopies still green. The timing was critical for eliminating complicating reflectance values from green herbaceous material. These reflectance values were compared to canopy cover of woody species measured on 1:50,000 scale black and white photographs using a point grid overlay corresponding to 10m intervals on the ground. Cover values measured from these photographs were checked for accuracy using 1:10,000 scale color photographs and ground measurements. No significant differences were found, and individual shrubs to 1m in diameter were detectable on the larger scale photographs. A number of MSS bands and combinations showed significant relationships (r values of 0.82 to 0.94). In mapping tests, the MSS data correctly classed about 80% of the woody cover classes.

national parks, disturbance, ecological processes, fragmentation, habitat management, landscape planning, aerial photography, Landsat, MSS, remote sensing, canopy cover, shrub, tree, cover classes, pattern, landscape change, pattern, regional planning.

1295. Walker, B. H. 1986. **An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation**. South African Journal of Wildlife Research. 6: 1-32.

field techniques, woodland, savanna, community composition, community change, monitoring examples.

1296. Walker, B. H. 1992. **Biodiversity and ecological redundancy**. Conservation Biology. 6: 18-23.

The author asserts that species vary in their importance for maintaining ecosystem function, some acting as "drivers" and others as "passengers." Because of this, the best way to reduce the decline of biodiversity is to focus initial attention on the elements of biodiversity necessary for the resilience of the ecosystem. The suggested approach begins by analyzing ecosystem function and the functional classification of the biota into guilds. Those guilds with one or few species are the most critical for immediate conservation focus. Other guilds should be evaluated further, to determine if hypothesized functional redundancy is actually demonstrable with density compensation after removal. The last step is to compare the relative importance of functional groups. Species-based approaches should not be replaced by this method, but complemented. A species-based approach that ranks species by taxonomic distinctness is important for local biodiversity.

biodiversity, ecological processes, ecosystem, indicators, community structure, community composition, functional groups, community-level, objectives.

1297. Walker, B. H. 1970. **An evaluation of eight methods of botanical analysis on grasslands in Rhodesia**. Journal of Applied Ecology. 7: 403-416.

In each of 15 macroplots in a bunchgrass community, 3 cover estimates (10m long line intercept; 125 points, each 3m apart and located by a wheel point instrument; 2 variable plots), 3 density measures (20x40cm quadrat counts; point-center quarter; angle order), frequency, and the dry-weight-rank yield measure were compared using 3 observers. The sample size required to be within 10% of the mean (95% confidence) and the time required were determined for each method. Of the 3 cover estimates, line intercept was superior to wheel points in terms of time required for similar accuracy, although the authors acknowledged that this was partially due to the sparseness of vegetation (<8% cover). The variable plot, although fast, was considered inferior because the irregular shape and hollow centers of tufts were included, resulting in overestimation of cover, and because it could only be used for bunchgrasses. The 2 distance density techniques gave an overestimate of density compared to quadrats, although they were much quicker. Frequency measures displayed good agreement between operators. Frequency was the only measure that would allow estimates by species with a reasonable precision and sample size. The dry-weight method was found inadequate because of large differences between observers.

community composition, density, distance methods, point-center methods, random pairs, cover, canopy cover, line intercept, point frames, point intercept, variable plots, weight estimate, observer variability, technique comparison, community-level, grassland, field techniques.

1298. Walker, D. A.; Walker, M. D. 1991. **History and pattern of disturbance in Alaskan arctic terrestrial ecosystems: a hierarchial approach to analyzing landscape change.** Journal of Applied Ecology. 28: 244-276.

A hierarchical scale of disturbance ranging from continental to microsite is used to examine patterns of disturbance in the Alaskan Arctic. A three-tiered Geographic Information System (GIS) of investigation and monitoring and the predictive models and linking elements between them is described. At the highest tier, satellite remote sensing (SRS) using Advanced Very High Resolution Radiometers (AVHRR) monitors primary productivity. At the next level, Landsat data and SPOT visible imagery combined with aerial photography monitors watershed level changes in land use and habitat. At the lowest level, photo interpretation is linked with ground studies which include vegetation mapping in 1000x1000m grids, and permanent 1x1m plots in which species occurrence and plant height are measured every 5 years. All of these studies are linked spatially through GIS.

Interaction between scales are evaluated using GIS and predictive models.
landscape-level, monitoring examples, disturbance, habitat management, pattern, landscape change, regional planning, scale, community composition, long-term ecological monitoring, aerial photography, GIS, Landsat, TM, AVHRR, MSS, remote sensing.

1299. Walker, J.; Tunstall, B. K. 1981. **Field estimation of foliage cover in Australian woody vegetation**. Tech. Memo. 81/8199. Canberry, Australia: Division of Land Use Research, Commonwealth Scientific and Industrial Research Organization (CSIRO). 18 p.
field techniques, cover, shrub.

1300. Walker, S. C.; Mann, D. K.; McArthur, E. D. 1996. **Plant community changes over 54 years within the Great Basin Experimental Range, Manti-La Sal National Forest**. Proceedings: shrubland ecosystem dynamics in a changing environment; 1996 May 23-25; Las Cruces, NM. Gen. Tech. Rep. INT-338. Ogden, UT: U.S. Department of Agriculture, Forest Service: 66-68.
community-level, community change, long-term ecological monitoring, monitoring examples, shrubland.

1301. Walker, S. C.; Stevens, R.; Monsen, S. B.; Jorgensen, K. R. 1995. **Interaction between native and seeded introduced grasses for 23 years following chaining of juniper-pinyon woodlands**. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 372-380.
Five-way exclosures at 3 sites, eliminating grazing of various combinations of deer, cattle and rabbits, were monitored for over 20 years after chaining and seeding of pinyon juniper woodlands. In each exclosure treatment, 5 permanent 30.5m transects were randomly located. Along each transect, the number of shoots (rhizomatous plants) or individuals were tallied in 10 contiguous 3.0x0.3m plots. Cover was measured along the transect with 200 point intercepts. Biomass was estimated using ocular estimates, improved by comparison with clipped samples. Differences (between years and treatment) were tested with a general linear model ANOVA, and correlations between estimates of cover, density, and biomass analyzed with the Pearson's product moment correlation. Analysis of trends over time compared native and non-native species, using pairwise yearly comparisons to search for significant change.
community-level, field techniques, cover, community composition, community change, rangeland, density, canopy cover, point intercept, production, biomass, detecting change.

1302. Waller, S. S.; Lewis, J. K.; Brown, M. A.; Heintz, T. W.; Butterfield, R. I.; Gartner, F. R. 1978. **Use of 35mm aerial photography in vegetation sampling**. In: Hyder, D. N., ed. Proceeding of the 1st International Rangeland Congress; 1978; Denver, CO. Denver, CO: Society for Range Management: 517-520.
Aerial photographs (scale about 1:3400) were used to stratify vegetation and soils. This stratification so dramatically improved efficiency of field sampling due to reduced number of plots needed to sample adequately, that even with the cost of the specially commissioned aerial flights overall costs were reduced.
rangeland, aerial photography, stratified sampling, vegetation treatments, remote sensing.

1303. Walters, C. J. 1986. **Adaptive management of renewable resources**. New York, NY: Macmillan. 374 p.
monitoring and management, adaptive management, objectives.

1304. Walters, C. J.; Collie, J. S.; Webb, T. 1988. **Experimental designs for estimating transient responses to management disturbances**. Canadian Journal of Fisheries and Aquatic Sciences. 45: 530-538.
design, detecting change, experimental design, aquatic.

1305. Walters, C. J.; Holling, C. S. 1990. **Large-scale management experiments and learning by doing**. Ecology. 71: 2060-2068.
The authors point out that "every major change in harvesting rates and management policies is in fact a perturbation experiment with highly uncertain outcome." Three adaptive management processes are identified: 1) evolutionary trial and error; 2) passive adaptive, where data are used to construct a single best model, and the decision is implemented as though this model were correct; and 3) active adaptive, in which a range of alternative models is considered, and a decision is made that reflects a balance between expected short-term performance and long-term value of knowing which model is best. In the last scenario, uncertainty about which model is correct is acknowledged, and a decision table of possible outcomes given policy options and alternate models is created, recognizing that the only way to know whether alternate models are correct is to try them (large scale experiments). The balance of learning and risks is tipped in favor of learning especially when there are a large number of similar units that can be managed independently to form a replicated experiment.
disturbance, ecological processes, ecosystem, ecosystem management, scale, large-scale monitoring, landscape-level, monitoring and management.

1306. Wang, D. 1986. **Use of statistics in ecology**. Bulletin of The Ecological Society of America. 67: 10-12.
Two general areas of misapplication of statistics are recognized. One source of error is assuming one of the following is true when it is not: 1) observations are normally distributed; 2) observations are randomly and independently distributed; 3) groups of observations have the same underlying distribution (homogeneity of variances).

Monitoring and other time series measurements often violate the second assumption because observations are not independent. The second source of error is to use improper statistical models, of which pseudoreplication is the most common.

analysis, replication, pseudoreplication, parametric statistics, time series, repeated measures analysis.

1307. Wang, Y.; LeMay, V. M.; Marshall, P. L. 1996. **Relative efficiency and reliability of parametric and nonparametric sequential accuracy testing plans.** Canadian Journal of Forest Research. 26: 1724-1730.

design, precision, sample size, analysis, randomization tests, parametric statistics, nonparametric statistics.

1308. Ward, R. C.; Loftis, J. C.; McBride, G. B. 1986. **The "data-rich but information poor" syndrome in water quality monitoring.** Environmental Management. 10: 291-297.

monitoring overviews, objectives.

1309. Warner, R. E. 1983. **Toward a strategy for inventory and monitoring riparian wetland systems.** In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 307-311.

In an overview of monitoring, the author describes 4 important stages: design, execution, analysis, and institutionalism. Challenges in each stage are varied and complex. In riparian areas, the challenges are especially difficult because of the high and varied resource values, the vulnerability to a number of disturbances, and the variable and complex structure. Typical aerial photography (1:80,000) is unable to distinguish any details other than the general location of riparian areas. Photography at scales of 1:6000 or 1:10,000 can be used to measure a number of characteristics such as riparian boundaries, land uses, plant species and community types, canopy cover. These data can be used to supplement and plan ground-based data collection. After testing various field techniques, a sampling point system arranged along a series of transects perpendicular to the water's edge was found most effective. At each point up to 25 different variables may be measured, depending on the objectives of the project.

monitoring examples, riparian, remote sensing, aerial photography, data management, vegetation mapping.

1310. Warner, R. E.; Katibah, E. F. 1981. **Measurement techniques for inventorying riparian systems.** In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 487-495.

Objectives of the California Riparian Study Program were to determine historical extent and present status of the riparian resource. Sites for ground-based sampling were chosen by first randomly choosing a topographic quadrangle, then a section, then a specific tract within that section. Ground-based sampling was standardized along transects placed perpendicular to the stream course. From 1:6000 scale aerial photography, width of the riparian area, percent woody crown cover, evidence of human use, number of snags, and other characteristics were evaluated.

riparian, sampling design, inventory, species lists, objectives.

1311. Warren, P. L. 1981. **Sampling and description of vegetation for large scale mapping at Organ Pipe Cactus National Monument.** In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 352-358.

Vegetation was mapped using 1:24,000 scale aerial photography combined with ground measurements using a releve approach (complete species list and estimated abundance) and visual estimates of total vegetation cover.

inventory, general examples, large-scale monitoring, community composition, species lists, vegetation mapping, desert, field techniques, cover, cover classes, ocular estimation, aerial photography, remote sensing, releve.

1312. Warren, P. L.; Hutchinson, C. F. 1984. **Indicators of rangeland change and their potential for remote sensing.** Journal of Arid Environments. 7: 107-126.

rangeland, indicators, remote sensing.

1313. Warren-Wilson, J. 1963. **Errors resulting from thickness of point quadrats.** Australian Journal of Botany. 11: 178-188.

Use of physical points, as opposed to optical crosshairs, results in an overestimation error in cover measure due to the diameter of the point. Error is related to leaf shape (long narrow leaves are overestimated more than round ones) and leaf size (the percent error relative to the true value is higher for smaller leaves). This error can be over 100% for fine-leaved plants, even with a point as small as 2mm diameter. The author suggests that an optical sighting apparatus be used, or that pins be sharpened to a fine point. Only the point be used for recording contacts, never the sides of the point.

field techniques, cover, canopy cover, point intercept.

1314. Warwick, R. M.; Clark, K. R. 1991. **A comparison of some methods for analyzing changes in benthic community structure.** Journal of the Marine Biological Association of the United Kingdom. 71: 225-244.

field techniques, community change, community composition, technique comparison, community-level, community structure, aquatic, analysis.

1315. Washington, H. G. 1984. **Diversity, biotic and similarity indices: a review with special reference to aquatic ecosystems**. Water Research. 18: 653-694.

analysis, similarity measures, aquatic, biodiversity, species diversity.

1316. Watt, T. A. 1993. **Introductory statistics for biology students**. New York, NY: Chapman and Hall. 200 p.

Presents introductory concepts in statistics using biological examples.

analysis, statistics overview.

1317. Weaver, J. C. 1995. **Indicator species and scale of observation**. Conservation Biology. 9: 939-942.

landscape-level, indicators.

1318. Weaver, J. E.; Albertson, F. W. 1943. **Resurvey of grasses, forbs and underground plant parts at the end of the great drought**. Ecological Monographs. 13: 63-117.

natural variability, community change, grassland, community-level.

1319. Webb, R. H.; Steiger, J. W.; Turner, R. M. 1987. **Dynamics of Mojave desert shrub assemblages in the Panamint Mountains, California**. Ecology. 68: 478-490.

general examples, community-level, shrub, shrubland, desert, community change.

1320. Wei, W. W. S. 1990. **Time series analysis: univariate and multivariate methods**. New York, NY: Addison-Wesley. 478 p.

analysis, time series.

1321. Weigel, J.; Britton, C. M. 1986. **Use of a metal detector to locate permanent plots**. Journal of Range Management. 39: 565.

The authors report employing metal detectors for locating permanent plots marked with underground metal stakes. This method is particularly useful in grazing studies or other situations where protruding plot markers are not desired. They suggest monumenting two corners of the plots with 35 cm lengths of 1 cm diameter steel reinforcing rod inserted vertically into the soil, flush or slightly below the soil surface. Nearby reference points are selected to establish approximate plot locations (e.g., fence corners). Soft aluminum tags are attached to these reference points with direction and distance to each numbered plot. Prior to each sampling period, a ferromagnetic metal detector is used to relocate plots. Corners can be temporarily marked with pin flags during sampling. The authors suggest iron markers are most easily detected. To enhance detectability in dense vegetation the authors suggest installing plastic-sealed magnetic caps over one marker per plot.

field techniques, monumentation, permanent plots, tools.

1322. Wein, R. W.; Rencz, A. N. 1976. **Plant cover and standing crop sampling procedures for the Canadian high arctic**. Arctic and Alpine Research. 8: 139-150.

Several sampling designs for plant cover and standing crop were tested to determine the best design(s) for a range of high Arctic vegetation types. At each of 3 study areas, a transect was delineated on an aerial photograph to capture the range of vegetation types occurring in the area for a total of 17 stands. Cover was measured with 10 sets of 5 contiguous line intercepts (each 1m long), with fifty 10 point pin frames, and ocularly estimated into 1 of 10 cover classes in 3 quadrat sizes (50x100cm, 50x50cm, and 50x25cm). Quadrats were also photographed and standing crop harvested. Standing crop was collected in 1m units in a 20cmx5m belt plot. The number of sampling units of each type required to estimate the mean within 20% with a 95% confidence level was calculated. The point method yielded means of 80% cover, compared to 50% for the field quadrat method and 60% for the photo quadrat and line intercept. Efficiency (time to reach the specified precision) was, in decreasing order: point intercept, line intercept, photo quadrat, and field quadrat. The same number of quadrats were required for each of the quadrat sizes, thus the most efficient was the smallest. For standing crop, the smallest quadrat size and the 100x20cm belt were most efficient.

field techniques, community-level, cover, community composition, canopy cover, line intercept, point frames, point intercept, ocular estimation, biomass, photoplots, production, technique comparison, cover classes, photoplots, precision, sample size.

1323. Weise, D. R.; Glover, G. R. 1993. **Selecting a sampling method to aid in vegetation management decisions in loblolly pine plantations**. Canadian Journal of Forest Research. 23(20): 2170-2179.

design, sampling design, tree, plotless methods, nearest neighbor, density, field techniques, technique comparison, variable plots.

1324. Welch, D. M.; Pierce, T.; Wiken, E. B. 1981. **Large area, low cost resource inventories -- Canadian programs, methods and costs**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 129-135.

Three examples of extensive resource inventory systems used in Canada are presented: the Canada Land Inventory (CLI), the Ecological Land Survey (ELS), and the Northern Land Use Information Series (NLUIS). The first covers areas of high population density and high value agricultural land across the southern part of the country, and is used for management of growth while protecting agricultural and natural resources. The ELS is used to classify the remainder

of the country into similar ecological types. It uses a hierarchical system ("Ecoprovince to Ecoelement") ranging at scales of 1:5,000,000 down to 1:2500. The NLUIS provides cultural information on settlement patterns and land use in the northern part of the country.

monitoring examples, landscape-level, pattern, ecosystem, ecosystem management, inventory, forest, large-scale monitoring, integrated monitoring.

1325. Wells, K. F. 1971. **Measuring vegetation changes on fixed quadrats by vertical ground stereo-photography**. Journal of Range Management. 24: 233-236.

Two 35mm cameras with 25mm lens, placed with lens centers 15cm apart and suspended 132cm above the ground, provided stereo pairs of a 1x1.5m quadrat. Simultaneous firing of cameras reduces blurring from vegetative movement and changes in light condition. Photographs were interpreted using a zoom stereoscope. Interpretation of species composition was aided by voucher collections made at the site. Percent cover was estimated using a grid system of points created by the crosshairs of the viewing scope and regular movement of the photo. A count of 200 points was completed in about 10 minutes for herbaceous cover. The photos could also be used to occularly estimate production, similar to estimates completed in the field.

field techniques, production, permanent plots, canopy cover, cover, point intercept, biomass, photoplots.

1326. West, N. E. 1983. **Choice of vegetation variables to monitor range condition and trend**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 636-639.

The author illustrates that traditional approaches to monitoring are rooted in concepts of Clementsian succession and the relatively simple vegetation of the Great Plains. Current ecological theory concerning succession and the highly variable and complex systems that must be monitored require careful choice of the measured variable. Biomass is highly variable, strongly affected by annual weather patterns. Canopy cover measurements may miss important successional changes that are occurring in the understory, but not yet apparent in the canopy (such as juniper invasion). Frequency is considered an artificial measure; the author notes that it cannot be estimated with the eye, only measured in plots. The interpretive power of frequency measures can be improved by using age, size, or vigor classes for each species, especially common or dominant ones. Since all methodologies have their drawbacks, the choice of the variable used must be specific to the vegetation and information needs of the situation.

field techniques, cover, vegetation sampling overview, monitoring overviews, community composition, community change, cover, density, canopy cover, frequency, biomass, production, community-level, rangeland, technique comparison.

1327. West, N. E. 1981. **Efficient measurement of arid zone vegetation utilization**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 421-424.

field techniques, utilization, desert, rangeland.

1328. West, N. E. 1985. **Shortcomings of plant frequency-based methods for range conditions and trend**. In: Krueger, W. C., chairman. Symposium on the use of frequency and density for rangeland monitoring: Proceedings of the 38th annual meeting, Society for Range Management; 1985 February 11-15; Salt Lake City, UT. Denver, CO: Society for Range Management: 87-90.

The main objection to use of frequency for monitoring rangeland trend is that the measure cannot be directly related to vegetation characteristics tied to management objectives such as the production of forage, the increase in vigor, density and production of desired species, or the provision of adequate cover for wildlife or watershed. Frequency estimates are sensitive to the detection of invasion (such as by brush seedlings), but once the invasive species has stabilized in colonization, freqency measures are no longer sensitive to increases in cover and production (such as when the brush species grow). Some of the limitations of frequency can be overcome by using size classes for recording species, rather than simply species presence or absence.

field techniques, community-level, rangeland, exotics, objectives, community change, community composition, rangeland, frequency, nested frequency, seedling, shrub.

1329. West, N. E.; Baasher, M. M. 1968. **Determination of adequate plot size by use of mean distance between salt desert shrubs**. Southwestern Naturalist. 13(1): 61-74.

By using a site with mapped individuals, the size plot that best estimated density and frequency was determined. The most efficient plot was 10 times as long as wide, and had a length 2.5 to 2.66 times the mean interplant distance. In this system, plants were dispersed randomly.

field techniques, plot dimensions, frequency, density, shrub, shrubland, precision.

1330. West, N. E.; Provenza, F. D.; Johnson, P. S.; Owens, M. K. 1984. **Vegetation change after 13 years of livestock grazing exclusion on sagebrush semidesert in central Utah**. Journal of Range Management. 37: 262-264.

shrubland, general examples, succession, rangeland, community composition, production, double sampling, community-level, field techniques.

1331. Wester, D. B. 1992. **Viewpoint: replication, randomization and statistics in range research**. Journal of Range Management. 45: 285-290.

The author identifies 4 components of experimental design that are useful in avoiding pseudoreplication: 1) the population to which inference is extended; 2) treatment(s) under study; 3) experimental units that are treated; and 4) the randomization rule used in assigning treatments to units. Four studies and their analysis techniques are used to illustrate these components and their application: regression analysis, analysis of variance for comparison of treatment means, contingency table analysis, and an analysis of variance situation with correlated errors. Each of these are described using two examples, one a "classical" example from a statistics text, and the second a similarly structured range vegetation study. These clearly illustrate some of the typical errors in interpreting the meaning of statistically significant results.

design, experimental design, pseudoreplication, random sampling, sampling design, statistical interpretation, analysis.

1332. Westman, W. E. 1985. **Ecology, impact assessment and environmental planning.** New York, NY: John Wiley and Sons. 532 p.

general book on monitoring.

1333. Westman, W. E.; O'Leary, J. F. 1986. **Measures of resilience: the response of coastal sage scrub to fire.** Vegetatio. 65: 179-189.

shrubland, shrub, prescribed fire, community-level, community change, general examples.

1334. Wheeler, P. R. 1962. **Penta prism caliper for upper-stem diameter measurements**. Journal of Forestry. 60: 877-878.

field techniques, tools, tree, shrub.

1335. White, L. M.; Newbauer, J. J.; Wight, J. R. 1978. **Vegetational differences on native range during 38 years in eastern Montana.** In: Hyder, D. N., ed. Proceedings of the 1st International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 260-262.

Vegetation was charted in 19 permanent 30x150cm plots from 1935 to 1976 on grazed bunchgrass range sites. Accurate charting was aided by the use of a 5x5cm grid placed over the plot. The charting method allowed comparison of density, cover, and frequency in any of a number of plot configurations created by combining contiguous 5x5cm plots. Presented in this paper are data from 3 years of changes in frequency in 10x10cm quadrats.

community-level, field techniques, rangeland, community change, charting, cover, frequency, density, long-term ecological monitoring, permanent plots.

1336. White, P. S. 1987. **Natural disturbance, patch dynamics, and landscape pattern in natural areas.** Natural Areas Journal. 7(1): 14-22.

special sites, landscape-level, natural areas, disturbance, patch dynamics, pattern, natural variability.

1337. White, P. S. 1979. **Pattern, process and natural disturbance in vegetation**. Botany Review. 45: 229-299.

landscape-level, natural variability, succession, disturbance, ecosystem, ecological processes, ecological models, predicting change.

1338. White, P. S.; Bratton, S. P. 1980. **After preservation: philosophical and practical problems of change.** Biological Conservation. 18: 241-255.

monitoring and management, objectives.

1339. White, P. S.; Bratton, S. P. 1981. **Monitoring vegetation and rare plant populations in U.S. national parks and preserves.** In: Synge, H., ed. The biological aspects of rare plant conservation. New York, NY: John Wiley and Sons Ltd.: 265-278.

This book chapter summarizes vegetation and rare plant monitoring in 33 U.S. Biosphere Reserves. The authors use Great Smokey Mountains National Park as a detailed case history of vegetation monitoring. In addition, they summarize results of a survey of monitoring programs in 33 Biosphere Reserves nationwide. Over 75% of the reserves surveyed had established permanent vegetation monitoring plots and completed floristic checklists. The authors discuss a variety of monitoring issues which are pertinent to designing any long-term ecological monitoring program.

baseline monitoring, ecological monitoring programs, long-term ecological monitoring, national parks, monitoring examples, special sites, rare species.

1340. White, W. E.; Lewis, C. E. 1982. **Establishing circular plot boundaries with a wedge prism and an adjustable target pole**. Journal of Range Management. 35: 677-680.

plot selection, field techniques, tools.

1341. Whitehouse, I. E.; Cuff, J. R. I.; Evans, G. R.; Jensen, C. 1988. **Trend in bare ground from tussock grassland surveys, Canterbury, New Zealand**. New Zealand Journal of Ecology. 11: 31-38.

grassland, general examples.

1342. Whitman, W. C.; Siggeirsson, E. J. 1954. **Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation**. Ecology. 35: 431-435.

A 300x500ft area was sampled using 120 line-intercept transects (10m long) and 3000 point intercepts (300 ten-point frames). Points were measured with pins lowered through the vegetation at a 45° angle; all contacts with vegetation were recorded as the pin was lowered. Of the 57 species occurring in the area, 51 were detected by the line-intercepts and 49 by the point intercepts. Not surprisingly, the all-contacts point interceptions resulted in higher cover values, about 50%

higher for all vegetative cover. While the number of line-intercepts or points needed to achieve a desired precision varied by species, the three most common species required 15 to 23 line transects compared to 1100 to 1400 point intercepts. Point intercepts generally would require less time to achieve the desired precision compared to line intercepts.

community-level, field techniques, cover, community composition, grassland, rangeland, line intercept, point frames, point intercept, technique comparison.

1343. Whittaker, R. H., ed. 1973. **Ordination and classification of communities**. Handbook of vegetation science, vol. V. The Hague, the Netherlands: Junk. 730 p.

This book is fairly old, but a still standard in multivariate analysis of community data. Its main value is thorough coverage of included techniques, an historical perspective on multivariate techniques, and the inclusion of European approaches to classification. It is one of the most complete references on direct gradient analysis. Its main weakness is the lack of information on newer techniques.

analysis, multivariate analysis.

1344. Whitton, B. A.; Kelly, M. G. 1995. **Use of algae and other plants for monitoring rivers**. Australian Journal of Ecology. 20: 45-56.

Plants are useful for monitoring water quality because they provide an integrated response to exposure to the full range of impacts occurring at a site. Three types of monitoring can be identified: 1) changes in populations of representative species; 2) changes in the whole photosynthetic community and; 3) various bioassay/bioaccumulation approaches. Each of these is extensively reviewed.

community-level, riparian, aquatic, indicators, community composition, community structure, community change, diversity indices, aquatic.

1345. Whorff, J. S.; Griffing, L. 1992. **A video recording and analysis system used to sample intertidal communities**. Journal of Experimental Marine Biology and Ecology. 160: 1-12.

field techniques, cover, video, aquatic.

1346. Whysong, G. L.; Brady, W. W. 1987. **Frequency sampling and Type II errors**. Journal of Range Management. 40: 472-474.

Power curves were generated for frequency sampling using computer simulations. Populations were randomly distributed in space, thus whether a cell ("plot") was filled or not was determined by a random number generator. Type I error rate was set to 0.05, and tested with a two-tailed test of proportions. Curves were generated for an initial frequency of 20% and for one of 50% by resampling the grid 10,000 times for each incremental change (e.g. from 20% to 21%). Using the standard number of frequency plots in most studies (100 plots), a decrease in frequency to 11% from 20% will be detected only about half of the time. If the Type II error rate is set equal to the Type I (0.05), then only a decrease from 20% to 5% or less frequency, or an increase to 41% or greater frequency will be detected by the standard frequency sampling design. For the 50% initial cover, 500 plots would detect a change to 41% or 59% frequency 90% of the time. The change detected by 200 plots was a decrease to 32% or less, or an increase to 68% or more. The authors conclude that current monitoring studies using frequency are probably underpowered (have a low likelihood of detecting real change) due to a small sample size.

field techniques, design, frequency, power, precision, Type I and Type II errors, sampling design, sample size.

1347. Whysong, G. L.; Miller, W. H. 1987. **An evaluation of random and systematic plot placement for estimating frequency**. Journal of Range Management. 40: 475-479.

The authors produced several computer-generated populations, with varying levels of frequency (occupation of one of 128,000 cells), number of clumps, and dispersion around each clump center. Sampling of these populations was done randomly (each cell a potential sampling "plot") and systematically along randomly located lines using three different distances between plots. Comparisons of the different sampling designs indicated that systematic samples were significantly affected by clumping, dispersion, and distance between plots. Random sampling gave frequency means that were unaffected by clumping or dispersion, and more consistently estimated population frequencies. Probability of Type I errors were higher in the systematic design compared to the random sampling design.

design, power, sampling design, systematic sampling, random sampling, precision, frequency, Type I and Type II errors.

1348. Wiant, H. V. 1972. **Form class estimates -- a simple guide**. Journal of Forestry. 70: 421-422.

tree, ocular estimation, performance, field techniques.

1349. Wiant, H. V. 1981. **Setting inventory objectives**. In: Lund, H. G.; Caballero, R. H.; Hamre, R. H.; Driscoll, R. S.; Bonner, W., tech. coords. Arid land resource inventories: developing cost effective methods; 1980 November 30-December 6; La Paz, Mexico. Gen. Tech. Rep. WO-28. Washington, DC: U.S. Department of Agriculture, Forest Service: 96-97.

Although focused on the design of a forest inventory, many of the issues raised are germane to monitoring in any habitat. Any information-gathering activity is a balance between resources available and information needed. A number of specific questions that must be answered (e.g., What precision? How will the information be used?) are listed in this paper.

inventory, forest, objectives, integrated monitoring, sampling design.

1350. Wickham, J. D.; Norton, D. J. 1994. **Mapping and analyzing landscape patterns**. Landscape Ecology. 9: 7-29.

landscape-level, pattern.

1351. Wiegert, R. G. 1962. **The selection of an optimum quadrat size for sampling the standing crop of grasses and forbs**. Ecology. 43: 125-129.

Five nested square quadrats ranging from $0.016m^2$ to $0.250m^2$ were used to assess the sampling efficiencies of various plot sizes for sampling standing crop in an old field. Optimality was defined in terms of both variance reduction and time costs. For clumped vegetation, large plots were more efficient, and for more evenly dispersed species, such as grasses, smaller plots were more efficient. The smallest quadrats exhibited some bias toward overestimation of the mean, likely the result of edge errors.

field techniques, biomass, production, pilot study, plot dimensions, precision.

1352. Wiegleb, G. 1989. **Explanation and prediction in vegetation science**. Vegetatio. 83: 17-34.

community-level, pattern, ecological processes, community composition, succession, predicting change, ecological models.

1353. Wiegleb, G.; Herr, H.; Todeskino, D. 1989. **Ten years of vegetation dynamics in two rivulets in lower Saxony**. Vegetatio. 82: 163-178.

monitoring examples, community change, community-level, riparian.

1354. Wiens, J. 1981. **Single sample, surveys of communities: are the revealed patterns real?** American Naturalist. 117: 90-98.

The species assemblages this paper discusses are avian communities, but the concepts and questions it raises are appropriate to measurement of any community attributes, including monitoring of plant communities. The author notes that substantial variability in avian population numbers or occurrences of species (coefficients of variation of 10% to 40%) can occur annually. In addition, populations can vary on small spatial scales, sometimes in opposite directions, from year to year. This suggests that the patterns displayed from samples collected in a single year, or multiple year samples from a single place, can be misleading.

biological significance, ecological models, monitoring and management, feedback loops, ecological processes, biodiversity, pattern, community composition, community structure, community-level, natural variability.

1355. Wiersma, G. B.; Davidson, C. I.; Mizell, S. A.; Breckenridge, R. P.; Binda, R. E.; Hull, L. C.; Herrmann, R. 1987. **Integrated monitoring in mixed forest biosphere reserves**. In: Johnson, J. L.; Franklin, J. F. K. R. G., eds. Research natural areas: baseline monitoring and management. Gen. Tech. Rep. INT-173. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 29-39.

monitoring examples, integrated monitoring, baseline monitoring, environmental monitoring programs.

1356. Wiersma, G. B.; Franklin, J. F.; Kohler, A.; Croze, H.; Boelcke, C. 1988. **Integrated global background monitoring network**. In: Schweitzer, G. E.; Phillips, A. S., eds. Monitoring and managing environmental impact: American and Soviet perspectives -- proceedings 5th U.S.-U.S.S.R. symposium on comprehensive analysis of the environment. Washington, DC: National Academy Press: 246-265.

monitoring examples, global change monitoring, integrated monitoring, environmental monitoring programs.

1357. Wiersma, G. B.; White, G. J.; Bruns, D. A. 1991. **Global environmental monitoring in wilderness and protected areas**. Pacific rim forestry, bridging the world: Proceedings of the 1991 Society of American Foresters national convention; 1991 August 4-7; San Francisco, CA. Bethesda, MD: Society of American Foresters: 225-230.

This paper presented at the 1991 Society of American Foresters Wilderness Working Group meeting provides a summary of global environmental monitoring. The authors review the history of such efforts and describe existing monitoring networks and programs for several countries. They outline the International Geosphere/Biosphere Program (IGBP) which aims to: "describe and understand the interactive physical, chemical, and biological processes that regulate the total earth system,...the changes that are occurring in this system, and the manner in which they are influenced by human activities." It is suggested that Wilderness provides important pristine reference sites that contribute to a global network of areas for monitoring.

monitoring examples, special sites, baseline monitoring, environmental monitoring programs, global change monitoring, natural areas.

1358. Wight, J. R. 1967. **The sampling unit and its effect on saltbrush yield estimates**. Journal of Range Management. 20: 323-325.

design, plot dimensions, sampling design, production, field techniques, shrub.

1359. Wilde, S. A. 1954. **Floristic analysis of ground cover vegetation by a rapid chain method**. Journal of Forestry. 52: 499-502.

field techniques, cover, line intercept.

1360. Wilke, D. S.; Finn, J. T. 1996. **Remote sensing imagery for natural resource monitoring. A guide for first time users**. New York, NY: Columbia University Press. 295 p.

remote sensing, GIS.

1361. Williams, B. G. 1993. **Biostatistics, concepts and applications for biologists**. New York, NY: Chapman and Hall. 201 p.

This statistics overview emphasizes an intuitive grasp of contents over mathematical formulas. Examples are from the biological sciences.

analysis, statistics overview.

1362. Williams, B. 1978. **A sampler on sampling**. New York, NY: John Wiley and Sons. 254 p.
design, sampling design, analysis.

1363. Williams, B. L.; Marcot, B. G. 1991. **Use of biodiversity indicators for analyzing and managing forest landscapes**. Transactions of The North American Wildlife and Natural Resources Conference. 56: 613-627.
biodiversity, indicators, landscape-level.

1364. Williams, B. K.; Titus, K. 1988. **Assessment of sampling stability in ecological applications of discriminant analysis**. Ecology. 69: 1275-1285.
analysis, multivariate analysis, community composition.

1365. Williamson, H. D. 1989. **Reflectance from shrubs and under-shrub soil in a semi-arid environment**. Remote Sensing of The Environment. 29: 263-272.
Spatial variability is problematic for measuring vegetation cover by remote sensing data (Landsat MSS) because the signature is influenced by both vegetation type and soil color. These attributes can affect the vegetation index independently of the amount of cover. Knowledge of soil spatial distribution and associated color and reflectance can increase the sensitivity of the remotely sensed data to cover changes.
remote sensing, Landsat, MSS, canopy cover, vegetation mapping.

1366. Williams, O. B. 1970. **Population dynamics of two perennial grasses in Australian semi-arid grasslands**. Journal of Ecology. 58: 869-875.
grassland, demographic techniques.

1367. Williams, O. B. 1969. **Studies in the ecology of the riverine plain: V. plant density response in a *Danthonia caespitosa* grassland to 16 years grazing by merino sheep**. Australian Journal of Botany. 17: 255-268.
general examples, long-term ecological monitoring, grassland, density, field techniques.

1368. Williams, P. H.; Gaston, K. J. 1994. **Measuring more of biodiversity: can higher-taxon richness predict wholesale species richness**. Biological Conservation. 67: 211-218.
Measurements of biodiversity based on complete species lists are extremely expensive to use, requiring specialized taxonomic skills and intensive surveys. There are three alternate approaches. Using correlating environmental variables is attractive because the data may already be available, or be easily generated by remote sensing techniques. This approach has limited application because the relationship of diversity and environment is often non-linear, and because our lack of knowledge requires extensive ground-truthing to test the hypothesized relationship. Indicator species or groups, such as birds or butterflies, have been used to predict overall species richness, but the hypothesis of "nested" composition has not been proven. Another possibility is using higher taxa levels, such as the number of families, as indicators of species richness. In an examination of ferns, butterflies, passerine birds, and bats, family richness accounted for >79% of the variance in number of species. Some drawbacks of this approach are limitations of comparisons caused by uneven sampling effort and taxonomic treatment and unusual cases of regions that have few higher taxa but a large number of endemic species within those taxa.
biodiversity, indicators, diversity indices, species diversity, species lists, functional groups.

1369. Williams, W. T.; Stephenson, W. 1973. **The analysis of three-dimensional data (sites x species x times) in marine ecology**. Journal of Experimental Marine Biology and Ecology. 11: 207-227.
analysis, multivariate analysis, community composition, community change, community-level.

1370. Willison, J. H. M.; Bondrup-Nielsen S.; Dyrsdale, C.; Herman, T. B.; Munro N. W. P.; Pollock. T. L., eds. 1992. **Science and the management of protected areas**. New York, NY: Elsevier. 548 p.
This book contains a chapter on "Protected areas and global change research, water chemistry, and data management." Topics addressed in this chapter include: monitoring for ecosystem integrity in Canadian National Parks; National Park contributions to long-term global change research; aquatic research and long-term monitoring in parks; and role of parks and protected areas in long-term environmental monitoring.
long-term ecological monitoring, national parks, protected areas, environmental monitoring programs, monitoring examples, special sites.

1371. Wilm, H. G.; Costello, D. F.; Klipple, G. E. 1944. **Estimating forage yield by the double sampling method**. Journal of The American Society of Agronomy. 36: 194-203.
field techniques, production, double sampling.

1372. Wilson, A. D. 1986. **The monitoring of changes in range condition: a multivariate site potential approach**. In: Joss, P. J.; Lynch, P. W.; Williams, O. B., eds. Rangelands: a resource under siege-- proceedings of the 2nd International Rangeland Congress; 1985; Canberra, Australia. Canberra, Australia: Australian Academy of Science: 517-521.
rangeland, community change, multivariate analysis, monitoring examples.

1373. Wilson, A. D. 1984. **Points of reference in the assessment of change in vegetation and land condition**. Australian Rangeland Journal. 6: 69-74.

reference areas, special sites, community-level, community change, rangeland.

1374. Wilson, J. B.; Roxburgh, S. H. 1994. **A demonstration of guild-based assembly rules for a plant community, and determination of intrinsic guilds**. Oikos. 69: 267-276.

functional groups, community-level, community composition.

1375. Wilson, M. V.; Shmida, A. 1984. **Measuring beta diversity with presence-absence data**. Journal of Ecology. 72: 1055-1064.

community-level, community composition, species diversity.

1376. Wimbush, D. J.; Barrow, M. D.; Costin, A. B. 1967. **Color stereo-photography for the measurement of vegetation**. Ecology. 48: 150-152.

field techniques, cover, remote sensing, photoplots.

1377. Windus, J. L. 1986. **Photo-quadrat and compass-mapping tools**. Natural Areas Journal. 6(1): 66-67.

field techniques, tools, photoplots, vegetation mapping.

1378. Winkworth, R. E. 1955. **The use of point quadrats for the analysis of heathland**. Journal of Botany. 3: 68-81.

field techniques, cover, point intercept, point frames, shrub.

1379. Winkworth, R. E.; Goodall, D. W. 1962. **A crosswire sighting tube for point quadrat analysis**. Ecology. 43: 342-343.

This paper illustrates the construction of a sighting tube to reduce the size of the points to near zero through the use of crosshairs, thereby reducing observer bias. Complete directions and schematics are included.

field techniques, cover, canopy cover, point intercept, tools.

1380. Winkworth, R. E.; Perry, R. W.; Rossetti, C. O. 1962. **A comparison of methods: plant cover in an arid grassland community**. Journal of Range Management. 15: 194-196.

Cover was measured by photographic techniques, ocular estimates in plots (circular 1.9cm diameter and rectangular 5x2cm and 10x4cm), line intercept, and point intercept on a bunchgrass rangeland. Points and plots were measured along 50m transects every 20cm (250 per transect). The same transect was used for line intercept. The circular 1.9cm diameter plot was identical to the Parker loop frame, but plants were counted as "in" only if cover was greater than 50%. The photos gave excellent representations, but it was impossible to identify concrete polygons to planimeter. The other methods gave similar cover results, with similar variances. Point and loop methods were the most rapid.

field techniques, cover, canopy cover, cover, line intercept, loop frames, point intercept, photoplots, ocular estimation, technique comparison.

1381. Winward, A. H.; Martinez, G. C. 1983. **Nested frequency--An approach to monitoring trend in rangeland and understory timber vegetation**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 632-635.

Frequency is a measure little affected by seasonal variations (if only plants rooted in the quadrat are considered), and robust to different observers because the only decision to be made is whether or not the species occurs within the plot. Because frequency is plot size dependent and because species abundances can cover such a range, a single plot size is not optimal for all species. All sampling units of a large plot, for example, may be occupied by a common species, resulting in a frequency of 100%. To address this challenge, the authors describe the nested frequency plot, which consists of a plot 5x5cm, nestled in a 25x25cm plot, within a 25x50cm plot, within the largest 50x50cm plot. This is the plot configuration widely adopted by natural resource agencies.

field techniques, frequency, nested frequency, rangeland.

1382. Wissmar, R. C. 1993. **The need for long-term stream monitoring programs in forest ecosystems of the Pacific Northwest**. Environmental Monitoring and Assessment. 26: 219-234.

general examples, long-term ecological monitoring, aquatic, riparian.

1383. Wolfe, D. A.; Champ, M. A.; Flemer, D. A.; Mearns, A. J. 1987. **Long-term biological data sets: their role in research, monitoring and management of estuarine and coastal marine systems**. Estuaries. 10: 181-193.

monitoring and management, long-term ecological monitoring.

1384. Woodley, S.; Kay, J.; Francis, G. 1993. **Ecological integrity and the management of ecosystems**. Delray Beach, FL: St. Lucie. 220 p.

adaptive management, landscape-level, ecosystem management, ecological processes.

1385. Woodley, S.; Theberge, J. 1992. **Monitoring for ecosystem integrity in Canadian national parks**. In: Willison, J. H. M.; Bondrup-Neilson, S.; Drysdale, C.; Herman, T. B.; Munro, N. W. P.; Pollock, T. L., eds. Science and the management of protected areas. Amsterdam, The Netherlands: Elsevier Scientific Publishers: 369-377.

landscape-level, ecosystem, large-scale monitoring, disturbance, ecosystem management, national parks, special sites.

1386. Worf, D. L., ed. 1980. **Biological monitoring for environmental effects**. Lexington, MA: Lexington Books, D. C. Health and Company. 227 p.

This book resulted from a workshop sponsored by the Water Resource Research Institute of the University of North Carolina. The book is somewhat dated (late 1970s) but much of the information, suggestions, and challenges remain pertinent to current monitoring. Its primary focus is biomonitoring--the use of organisms to monitor occurrence and effects of pollutants, primarily in aquatic systems. Chapters include discussions of use of benthic macroinvertebrates, bioaccumulation in plants as indicators of contaminants, and overviews of Federal and State biomonitoring programs. Chapters with direct applicability to monitoring terrestrial vegetation are annotated separately.

ecological models, monitoring and management, disturbance, ecological processes, indicators, monitoring overviews.

1387. Wright, G. R.; Bunting, S. C. 1994. **The landscapes of Craters of the Moon National Monument: an evaluation of environmental changes**. Moscow, ID: University of Idaho Press. 103 p.

Thirty four contemporary photographs are matched with photographs taken from 1923 to 1965 to illustrate changes over time. The photos illustrate changes in limber pine and Douglas-fir density, changes in aspen communities, effects of fire, and development for recreation.

field techniques, monitoring examples, photopoints, long-term ecological monitoring, large-scale monitoring.

1388. Wright, R. G. 1972. **Computer processing of chart quadrat maps and their use in plant demographic studies**. Journal of Range Management. 25: 476-478.

Chart quadrats are a standard range monitoring method. In these, the vegetation in permanent $1m^2$ quadrats is mapped onto a standard 8x8 inch form using a pantograph. This paper describes computer scanning 180 chart quadrats from the Journada Experimental Range (NM). Some of these have been annually mapped for 50 years. Demographic information on life span and mortality of common species was generated using information from these quadrats and the computer scanning technique. Although the computer technology described in this paper is now obsolete, the concept is a useful one for treatment of pantograph data at other sites.

community composition, community structure, cover, grassland, rangeland, shrub grassland, long-term ecological monitoring, density, charting, canopy cover, demographic techniques, field techniques, community-level.

1389. Wu, S.; Zidek, T. 1989. **Selected methods for analyzing trends in environmental data series**. Tech. Rep. 127. New Canaan, CT: Sims Publications.

analysis, trend analysis.

1390. Yandle, D. O.; Wyant, H. V. 1981. **Comparision of fixed-radius circular plot sampling with simple random sampling.** Forest Science. 27: 245-252.

design, sampling design, random sampling.

1391. Yoccoz, N. G. 1991. **Use, overuse and misuse of significance tests in evolutionary biology and ecology**. Bulletin of The Ecological Society of America. 72: 106-111.

The author notes two problems in the application of statistical tests in ecology. First, differences may be statistically different without being biologically different. Differences are often reported in the literature as "significant" without providing the reader with information about the magnitude of the difference. The size of a biologically important difference should be determined before the experiment begins, and the sampling design developed to test that difference. Second, in most cases where statistical test are used, a p-value of 0.05 is standard, with no consideration of the implications of the choice of the value. Consideration of the power of the test is rare.

biological significance, statistics overview, Type I and Type II errors, precision, power.

1392. Yorks, T. P.; West, N. E.; Capels, K. M. 1994. **Changes in pinyon-juniper woodlands in western Utah's Pine Valley between 1933 and 1989**. Journal of Range Management. 47: 359-364.

The authors examined changes in pinyon-juniper plant communities during a 56-year period in the Pine Valley in southwestern Utah. They utilized data from a 37km long transect established in the Pine Valley in 1933. Circular $19m^2$ plots were located at 42m intervals along the transect. Land management practices during the period from 1933 to 1989 included a reduction of livestock grazing and some chaining and burning of pinyon-juniper vegetation. The authors reexamined the transect in 1989 with an updated version of the original "square-foot-density" method. Density and cover data between the two time periods were analyzed using a t-test.

woodland, monitoring examples, long-term ecological monitoring, succession, density, disturbance, field techniques, frequency, cover, community change, community-level.

1393. Yorks, T. P.; West, N. E.; Capels, K. M. 1992. **Vegetation differences in desert shrublands of western Utah's Pine Valley between 1933 and 1989.** Journal of Range Management. 45: 569-578.

This paper reports on changes in desert shrubland communities over a 56-year period in the Pine Valley in southwestern Utah. See Yorks and others (1994) for the companion paper on changes in woodland communities and a description of the overall study.

succession, monitoring examples, long-term ecological monitoring, shrubland, density, ocular estimation, cover, frequency, community change, community-level.

1394. Young, D. S. 1983. **Multi-resource analysis by geostatistical techniques**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends: Proceedings of an international conference; 1983 August 15-19; Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry: 475-479.

Geostatistics deals with the analysis of spatially autocorrelated phenomena in which, for example, the similarity between two plots can be partially explained by the distance between them. A brief introduction to the concepts of variograms and kriging is provided. In an example the techniques are illustrated for a woodland in which basal area was measured in 125 contiguous 1/5 acre plots. This database allowed the comparison of 3 common geostatistical sampling designs (regular grid, continuous strip, and discontinuous strip). Kriged means were more accurate and precise than means estimated by standard techniques. Because of the inclusion of spatial pattern, geostatistics yields more information from the same dataset compared to standard techniques, and is a tool that should have more wide-spread use in natural resource inventory and monitoring.

pattern, analysis, design, sampling design.

1395. Young, L. J.; Young, J. H. 1991. **Alternative view of statistical hypothesis testing**. Environmental Entomology. 20: 1241-1245.

This paper is a response to arguments that estimation and confidence interval analysis is more effective than hypothesis testing. The authors argue that the problem most commonly cited for hypothesis testing--the equating of statistical and biological significance--is rare in practice. Most experiments are underpowered (there is real biological change that is undetected by the design) rather than too powerful (insignificant biological changes are detected by the design). Experimenters should utilize power analysis to design experiments that detect the level of change considered biologically important. Failure to do so will usually result in inadequate sampling (number of replicates), and occasionally in over-sampling. This conclusion is supported and illustrated with a worked example.

experimental design, detecting change, power, precision, replication, sampling design, confidence intervals, statistical interpretation, analysis, design.

1396. Youtie, B. A.; Griffith, B.; Peek, J. M. 1988. **Successional patterns in bitterbrush habitat types in north-central Washington**. Journal of Range Management. 41(2): 122-126.

The authors describe a study of 25 plant communities within 3 bitterbrush habitat types along the Columbia River in Washington. The purposes of the study were to determine the relationship between topographic and edaphic site factors and bitterbrush habitat types, and to describe seral communities within these types. Vegetation frequency and cover measurements were taken within microplots and along line-intercept transects in each of the selected communities and analyzed utilizing multivariate techniques. Soil and environmental data were also recorded and analyzed.

shrubland, canopy cover, line intercept, ocular estimation, general examples, community composition, rangeland, shrub grassland, shrub, field techniques, community-level, frequency.

1397. Zamora, B. A. 1981. **An approach to plot sampling for canopy volume in shrub communities**. Journal of Range Management. 34: 155-156.

Canopy volume is the three-dimensional space occupied by a species or individual within the area from the ground to the top of the canopy. A plot sampling method is described for measuring canopy volume and effectively applied in dense shrub communities. The plot is 1 meter on a side at ground level and 3m tall. One side of the plot is marked by a tape; 2 sides marked by 1m long poles demarcated into decimeters, which are laid perpendicular to the tape. A third pole is placed vertically in one corner of the plot. For each species, the volume of all individuals with portions occurring within the plot are grouped, and the species assigned a volume class. Sample size necessary to reach an estimate of volume within 10% of the mean with a 90% confidence in the vegetation ranged from 107 to 764 plots.

community composition, community structure, cover, shrubland, coniferous forest, canopy cover, canopy volume, community-level, shrub, field techniques, tools.

1398. Zar, J. H. 1984. **Biostatistical analysis**. Englewood Cliffs, NJ: Prentice Hall. 717 p.

This book is a standard biostatistics texts. The book is designed as an introductory text but the subject matter is complete, including enough options in statistical tests to meet most of the situations encountered in biological data. The book is also designed as a reference, and thus contains complete statistical tables. Calculations for all analyses are included. Many of the explanations require the reader to understand the formulas presented, but the formulas are fairly simple (elementary algebra level). All methods are illustrated with numerically simple examples.

analysis, statistics overview.

1399. Zeide, B. 1980. **Plot size optimization**. Forest Science. 26: 251-257.

design, plot dimensions.

1400. Zhang, R.; Warrick, A. W.; Myers, D. E. 1994. **Heterogeneity, plot shape effect and optimum plot size**. Geoderma. 62: 183-197.

Because of spatial soil heterogeneity, sampling design must include the consideration of shape and size of plots to reduce variance between plots. In this paper, a general empirical equation for characterizing heterogeneity is derived and tested on various sets of published experimental data. The effects of various plot shapes are evaluated. The coefficient of variation decreases as plots become larger and as the width to length ratio decreases. Optimum plot size balances

precision and cost. These optimum plot sizes and the relative sample costs are related to variogram parameters, based on the relationship between the indices of heterogeneity and the geostatistical models.

design, precision, sample size, sampling design, plot dimensions.

1401. Zielinski, W. J.; Stauger, H. B. 1996. **Monitoring *Martes* populations in California: survey design and power analysis**. Ecological Applications. 6(4): 1254-1267.

This paper describes a monitoring program for two carnivores, the fisher and the American martin. It is applicable to vegetation monitoring as an example in which the power of the study to detect declines is explicitly evaluated during planning. Monte Carlo simulations were used to determine the sample size necessary to detect 20% to 50% declines with an 80% power.

monitoring examples, design, power, sample size, Type I and Type II errors, randomization tests.

1402. Zimmerman, G. M.; Goetz, H.; Mielke, P. W. 1985. **Use of an improved statistical method for group comparisons to study effects of prairie fire**. Ecology. 66: 606-611.

prescribed fire, grassland, community-level, community change, general examples, multivariate analysis, similarity measures, analysis.

1403. Zimmerman, G. T.; Neuenschwander, L. F. 1984. **Livestock grazing influences on community structure, fire intensity and fire frequency within the douglas-fir/ ninebark habitat types**. Journal of Range Management. 37: 104-110.

This paper documents the results of a study examining the influence of livestock grazing and fire disturbance in Douglas-fir/ninebark communities along the western slope of the Bitterroot Mountains in Idaho. Eighteen 15x25m macroplots were established both inside and outside of grazing exclosures in 1978, paired by slope, aspect, and soil series. Macroplots were sampled for cover, frequency, production, number of trees, basal area, shrub density, and accumulation of downed woody fuels. Each macroplot was divided into three 5x25m sections. Within each of these sections fifty 20x50cm microplots were placed at 1m intervals. Herbaceous species cover, rooted frequency, and production were measured in these microplots. Data were analyzed using ANOVA and t-tests.

disturbance, general examples, community comparisons, cover, density, frequency, production, field techniques.

1404. Zobel, M. 1993. **Changes in pine forest communities after clear-cutting: a comparison of two edaphic gradients**. Annales Bontanici Fennici. 30(2): 131-137.

community-level, community change, community comparisons, forest, general examples.

1405. Zonneveld, I. S. 1978. **A critical review of survey methods for range management in the third world with special emphasis on remote sensing**. In: Hyder, D. N., ed. Proceedings of the 1st International Rangeland Congress; Denver, CO. Denver, CO: Society for Range Management: 510-513.

Recommends 1:40,000 to 1:50,000 scale super wide angle black and white aerial photography for classification of desert vegetation.

remote sensing, rangeland, aerial photography, vegetation mapping.

1406. Zsilinszky, V. G. 1963. **Photographic interpretation of tree species in Ontario**. Ottawa, Ontario, Canada: Ontario Department of Lands and Forests. 80 p.

aerial photography, remote sensing, community composition, tree, forest.

Keyword Index

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Elzinga, Caryl L.; Evenden, Angela G., comps. 1997. Vegetation monitoring: an annotated bibliography. Gen. Tech. Rep. INT-GTR-352. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 184 p.

This bibliography of 1,400 published and unpublished references provides managers, ecologists, and scientists access to a great volume of literature addressing many aspects of vegetation monitoring: planning and objective setting, choosing vegetation attributes to measure, sampling design, sampling methods, statistical and graphical analysis, and communication of results.

Keywords: ecological monitoring, plant community monitoring, monitoring techniques, monitoring bibliography

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